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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 19

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CONTENTS

The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may apply for election to the Society. For further details write to the Secretary, Castle Museum, NORWICH, NOR 65B.

Copies of this Bulletin may be obtained 60p (post free) from the Society at the Castle Museum, Norwich, NOR 65B; it is issued free to members.

Also available at 75p (post free) is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

BULLETIN of the GEOLOGICAL SOCIETY OF NORFOLK
No.19 April 1971
Editor: R. S. Joby

EDITORIAL

This Bulletin continues in a new format the Bulletin of the Geological Society of Norfolk (formerly the Paramoudra Club). Earlier numbers, which were produced by duplicator from 1952 to 1970 are still available from the Hon. Secretary (for address see back cover) at 18p per copy, (20p inclusive of postage).

It is hoped that the more permanent form of this publication will attract a greater variety of papers than hitherto, on any topic relating to the geology of East Anglia, and I shall be very glad to receive manuscripts, preferably typewritten, at any time. For the next issue, due out in the late summer or early autumn of 1971, I should receive these as soon as possible and no later than June 30, 1971. My address is: 116 Gowing Road, NORWICH, NOR 40M.

R. S. J.

SOIL SURVEYING IN NORFOLK AND SUFFOLK

W.B. CORBETT

This paper describes the soils and soil patterns found in three parts of East Anglia: the Brecklands in the centre, the Beccles area in the east, and the Cromer Ridge in the north-east.

The present policy of the Soil Survey of England and Wales is detailed mapping of selected Ordnance Survey 1:25,000 sheets. The selected sheets for Norfolk and Suffolk are shown in Fig.1. In this programme, started in 1967, the Beccles sheet TM49 and the Cromer Ridge sheets TG13 and 14 have been completed, and the Horning sheet TG31 is being surveyed. Prior to this programme, from 1947 to 1966, the Survey used mainly third edition O.S.1" base maps, and mapped areas of 216 square miles selected for the agricultural importance of the soils. 80 square miles in Breckland were surveyed between 1960 and 1963 as a special project for the Forestry Commission and Nature Conservancy. The selected 1:25,000 sheets in the present programme, each covering about 38 square miles, will serve as the basis for 1:250,000 maps of counties, the 1:25,000 sheets being chosen as representing typical landscapes. The 1/4 inch maps will be largely produced by extrapolating major soil boundaries with the aid of relief maps or stereoscopic aerial photographs.

Each area has a distinctive group of soils arranged in characteristic patterns and these will be used to illustrate the two aims of soil survey, namely classification and mapping.

First, however, some soil definitions:

<u>Soil</u> - the surface zone above unweathered 'rock', influenced by three general processes: the addition to the surface of organic matter, physical and chemical

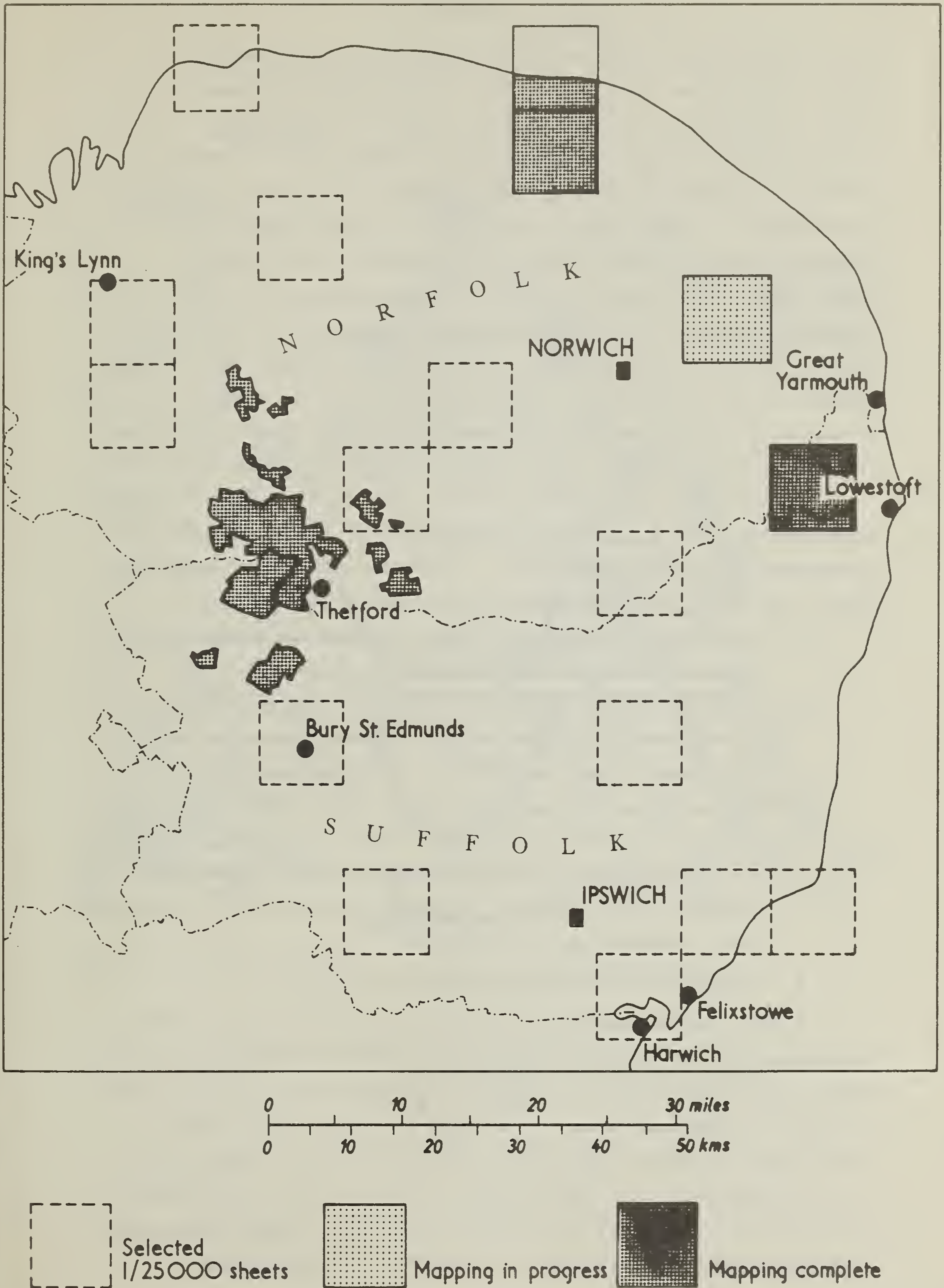


Fig. 1 Location and Policy

weathering, and the translocation of constituents. These processes combine to differentiate the zone into roughly horizontal layers known as horizons, the sequence of these between the unweathered 'rock' and the ground surface being known as the soil profile. Processes of importance in classification are decalcification, the removal in solution of $CaCO_3$; lessivage, the translocation in suspension of clay; podzolization, the translocation downwards of colloidal humus, iron and aluminium, alone or together, following chemical weathering of clay minerals in the upper profile in acid conditions; and gleying, the reduction and translocation of iron salts in anaerobic conditions.

Individual horizons in a soil profile are described separately, and annotated according to their nature in relation to soil formation. Five main annotations are used - A, B, C, E and g:-

- A the surface horizon whose colour is determined largely by its organic matter content.
- B the weathered subsoil, differentiated from the unweathered substrata by colour, largely of hydrated iron compounds, or by structure.
- C the little altered rock or parent material below.
- E horizons which have lost clay, or humus, or iron and aluminium; the suffixes t,h and fe being added to B horizons in which translocated material has accumulated.
- g a suffix indicating gleyed horizons.

Soil classification at the lowest level involves the grouping of similar profiles into soil series, the basic taxonomic unit. Where covering large areas, this is also a mapping unit. Series are given the name of the place in which they were first found or where they are widespread. A series has a particular arrangement of horizons, indicating predominance of a specific soil-forming process, a range or sequence of textures, a

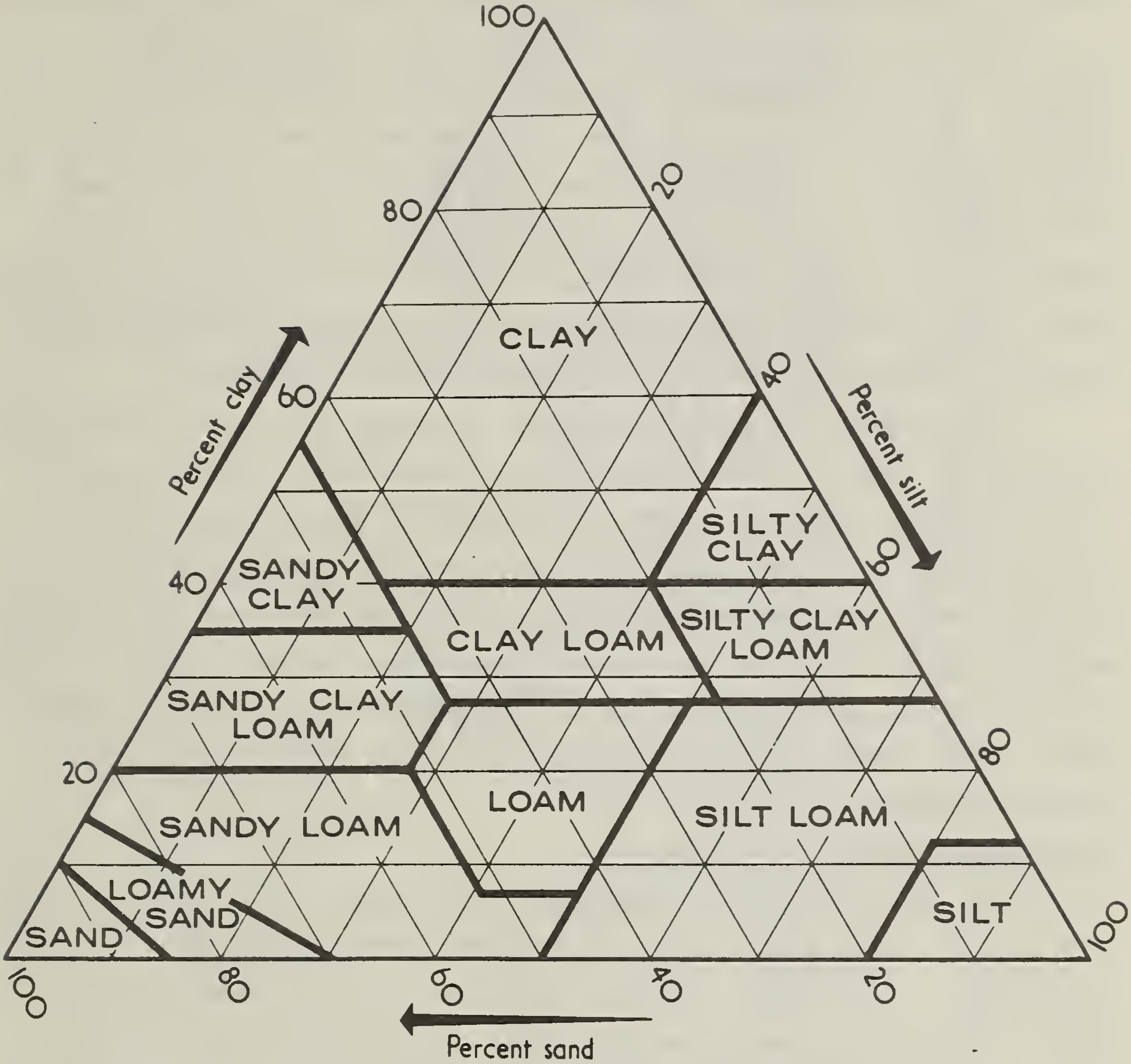


Fig. 2 Soil texture

particular moisture regime, and falls in one or possibly two soil drainage classes.

The main texture classes used by the Survey are shown in Fig.2. The three co-ordinates are: clay up to 2 microns, silt 2 to 50 microns, and sand 50 microns to 2 mm., each textural class being defined by a particular range of percentage composition for each of the fractions.

Soil drainage classes, Fig.3, are defined by the depth to, and frequency of, saturation, and in this country particularly by the rise in regional or local water tables in winter. The depths of 30, 60, 90 cms are chosen in relation to agricultural land use, months being used as the time unit. The five drainage categories are, well-drained, moderately well-drained, imperfectly drained, poorly drained, and very poorly drained.

For example, an imperfectly drained soil is saturated within 30 cms of the surface for less than three months in the year, and at depths between 30 and 60 cms for up to 6 months. Each moisture regime, so defined, is associated, in general terms, with a particular profile morphology. In the diagram, long-term saturation resulting in gleying is shown by coarse stippling, and short-term saturation causing ochreous mottling by the finer stipple.

Breckland Drift Soil Pattern

The Brecklands in central East Anglia lie in a gap in the Chalk escarpment between Newmarket and Swaffham. The main upland surface, at just over 100 feet, drains to the west by three rivers to the Great Ouse. The landscape (Fig. 4), except for the upland facet, consists of extensive gentle slopes of about 2 degrees, with relatively narrow terraces at between 25 and 50 ft. Dry secondary valleys intersect the uplands, and where these drain directly to the Fens the lower valley floors are extensive and delta-shaped.

Over 90 per cent of the soils of this landscape are on one parent material, a drift almost entirely of chalk

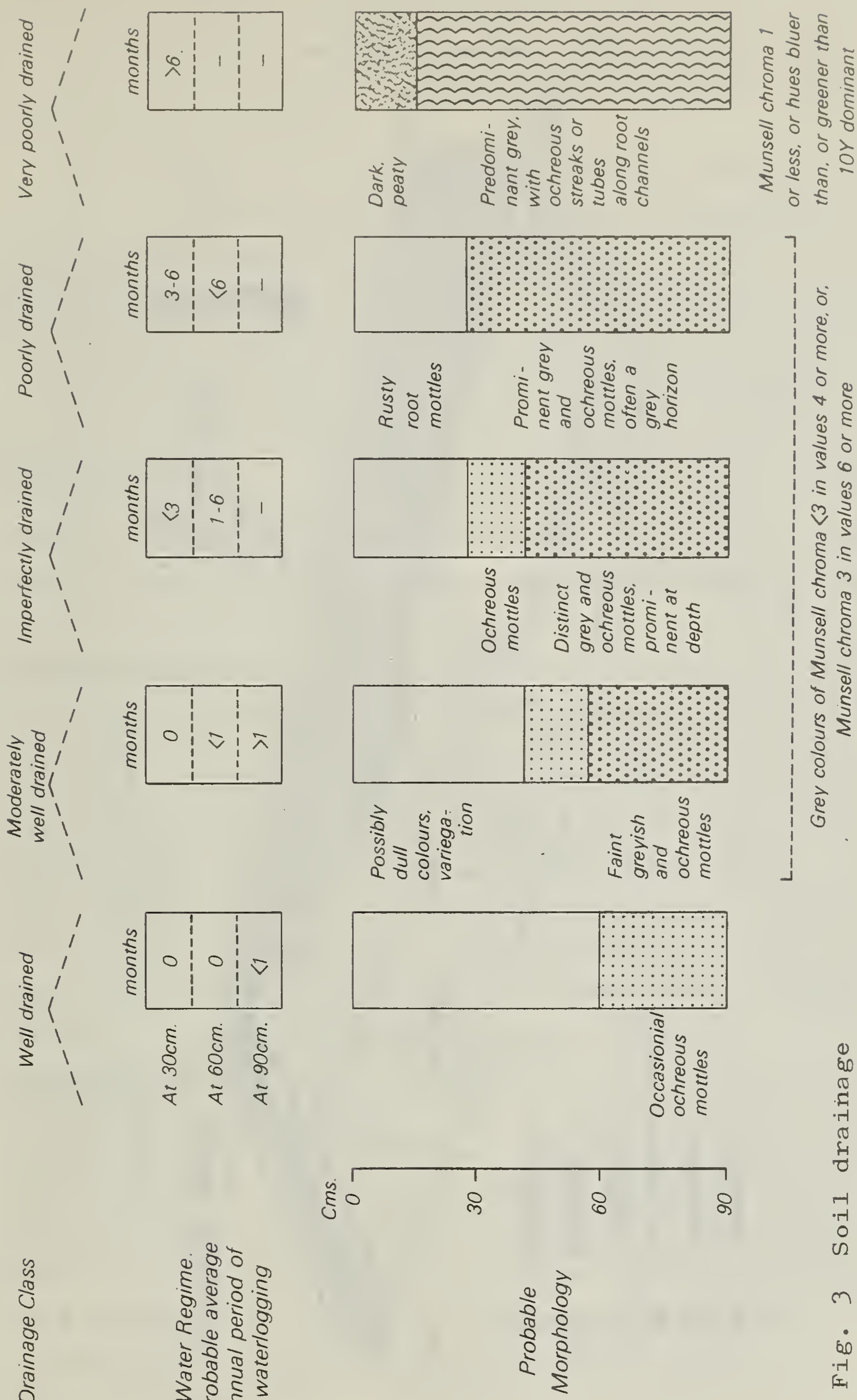


Fig. 3 Soil drainage

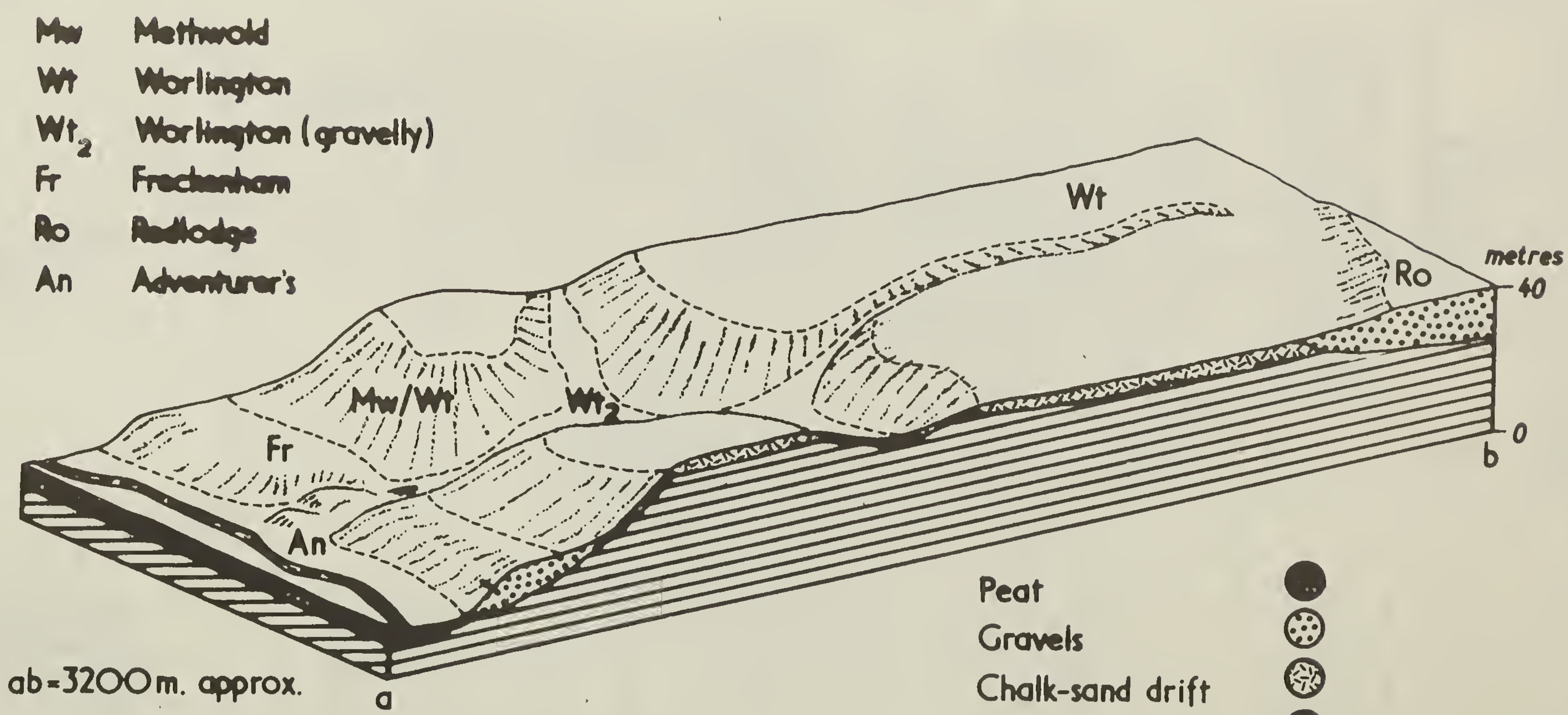


Fig. 4 Breckland - landscape and soils

and sand forming a very shallow skin over the Upper Chalk. The remaining ten per cent are on Sand and Gravel, on terraces and occasional upland caps or knolls, and on the floors of dry valleys.

The morphology of the drift soils is shown in Figs. 5 and 6. These are all well drained, with textures of sand or loamy sand.

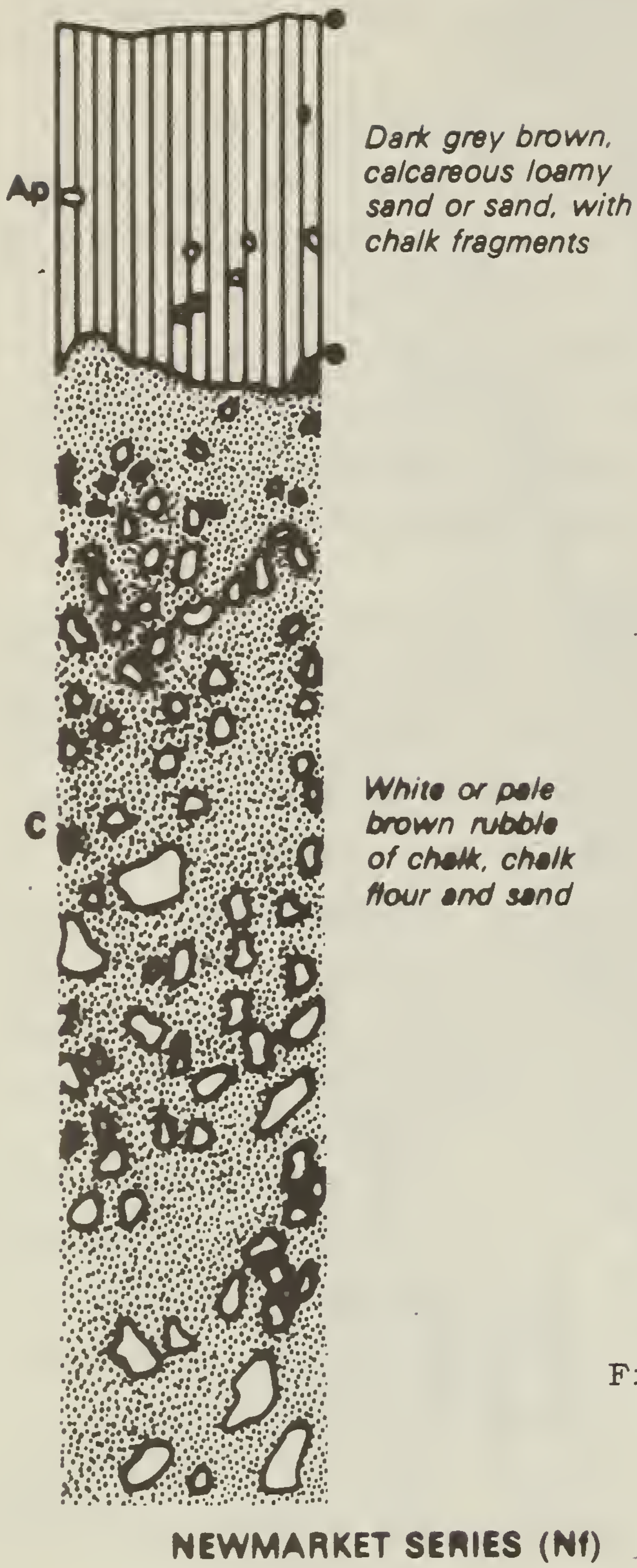
Newmarket Series - a shallow calcareous soil with two horizons, the surface A horizon with humus incorporation covering the little altered C horizon of chalk-sand drift. The main soil-forming process is decalcification.

Methwold Series - relatively shallow calcareous soils with three horizons, the A and C as above, with a brown, slightly calcareous B horizon partly decalcified, and without humus between. The main soil-forming process is also decalcification.

Worlington Series - a deep acid soil with four horizons, an acid A horizon with humus over a broad Eb horizon from which some clay has been eluviated. Below, at the chalk-sand drift surface, is a distinctive thin reddish brown layer of sandy loam or sandy clay loam. This is a Bt horizon formed, at least in part, by translocated clay. The C horizon is the unaltered chalky drift. The main soil process is lessivage, the eluviation of clay following decalcification from the acid upper profile and its accumulation at the calcareous drift surface.

Santon Series - a deep, markedly acid, soil with six horizons, having an A, Ea, Eb, B, Bt, C, horizon sequence. The A with much organic matter, and bleached grains is over a slightly indurated Bh horizon, dark or black and with sand grains cemented by translocated colloidal humus. Below is a Eb, Bt, C horizon sequence similar to the Worlington series. The dominant soil-forming process is podzolization, here mainly the translocation of colloidal humus from the surface to the upper part of the profile.

The four soils form a pedological sequence, although



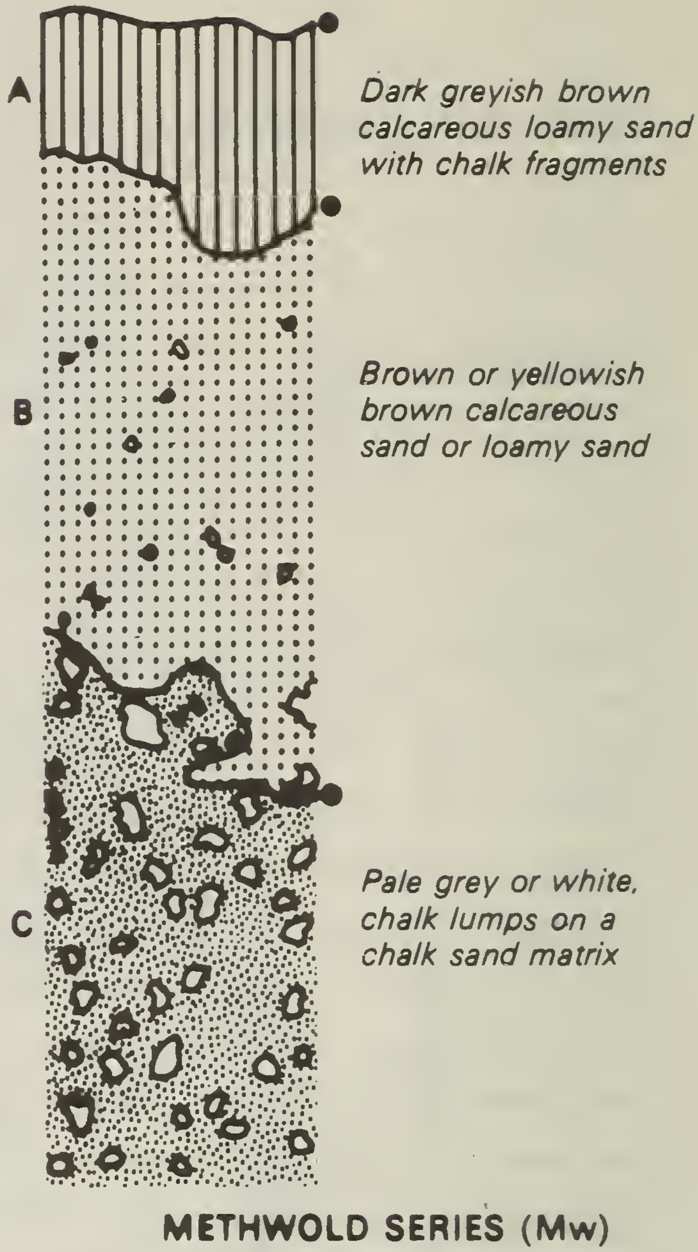


Fig. 5 Breckland Soils - profile morphology (A)

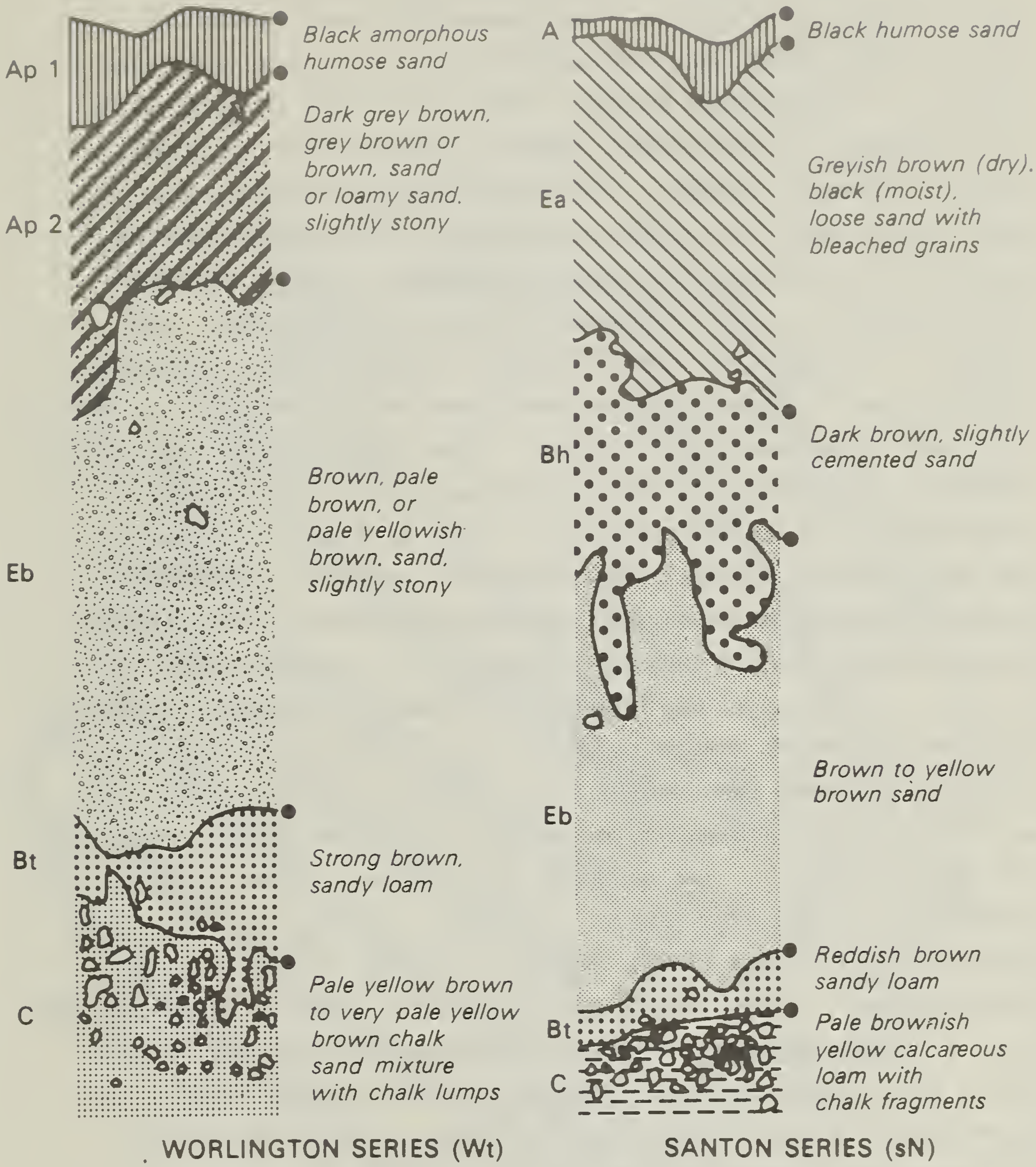


Fig. 6 Breckland Soils - profile morphology (B)

no single profile has been through all stages of development. The sequence is one of increasing depth of decalcification from about 20 to 120 cms, increasing acidity from alkaline to pH values below 4, eluviation of clay and finally eluviation of colloidal humus.

The soils occur in different positions in the landscape, shown in Fig.4. The Newmarket and Methwold Series, the shallower calcareous soils, occur only on slopes. The Santon Series, the deep acid podzol with a Bh horizon of colloidal humus, occurs only on flat, central upland, sites. The Worlington Series, the moderately deep to deep acid with a clay enriched Bt horizon, on the uplands and on slopes. This general distribution in the landscape facets is distinct and simple. The local distribution within facets is more complicated. Fig.7 shows that the drift surface is not even but undulates regularly. The undulations have a vertical magnitude of 25 to at least 100 cms and a frequency of 7 to 10 metres. They are an instance of the well known stripes and polygons pattern formed by periglacial cryoturbation, and on the slope and upland facets they reflect directly the local distribution of soils. On slopes the shallow calcareous Methwold and Newmarket Series occur on the crests of the drift undulations and the moderately deep acid Worlington with the clay accumulation at the drift surface, over the depressions. On uplands on central sites with polygons, Worlington soils occur on crests and the Santon Series, the humus podzol, can be found in depressions. The local soil patterns affect plant growth. Fig. 7 shows *Calluna* stripes in *Agrostis*-*Festuca* Grassland, the acidophyllous *Calluna* on Worlington soils in depressions, and calcicolous grass heath on Methwold and Newmarket soils on crests. Similar patterns are reflected in crop growth on arable land.

In this landscape the boundaries on maps at the 2½ inch scale delineate, in general, only the landscape

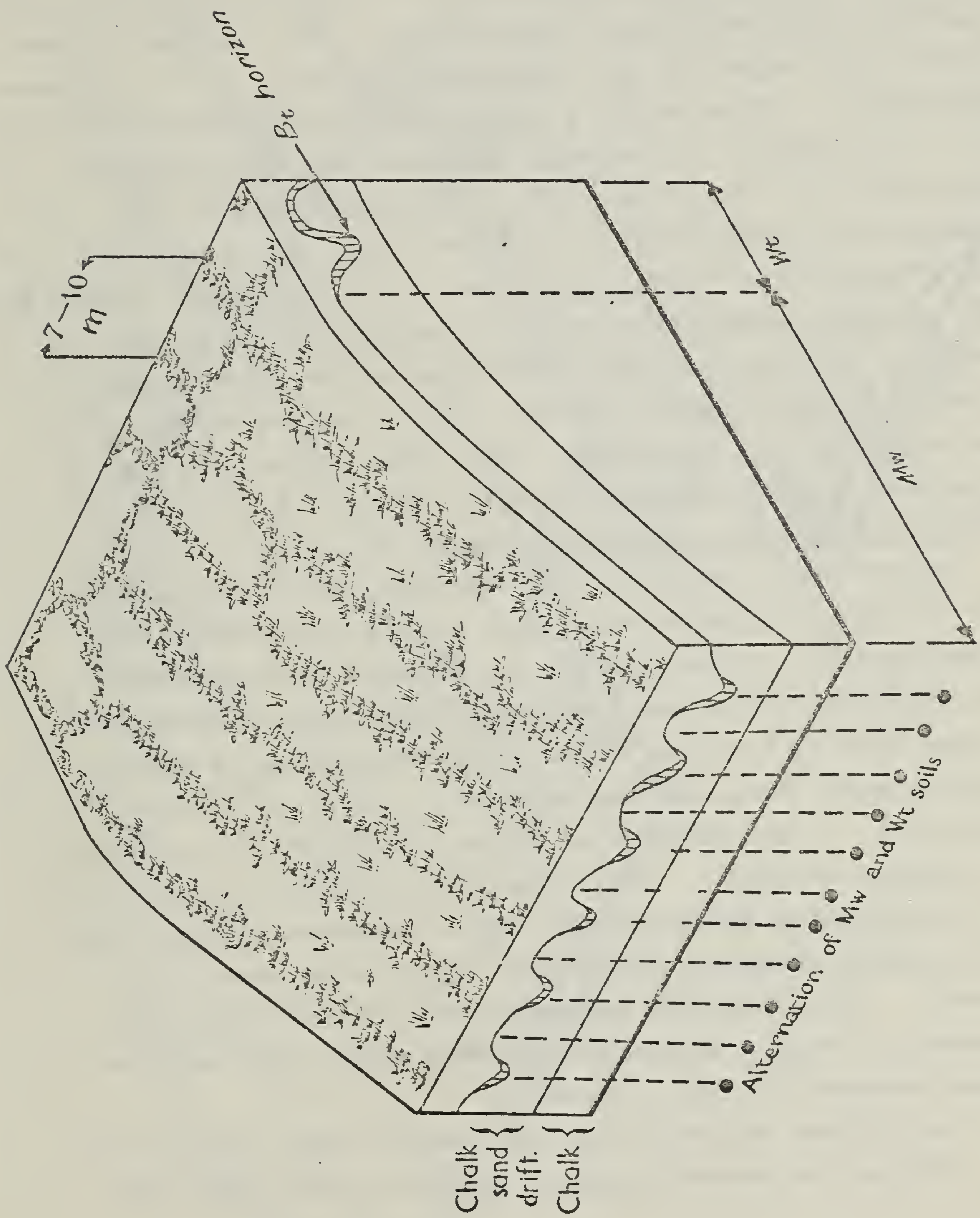


Fig. 7 Breckland Soils - local distribution

facets; uplands with Worlington soils, or a Worlington/Santon compound unit, and slopes with compound mapping units of the Methwold, or Newmarket with Worlington soils. Variation within facets is accounted for by compound mapping units.

Points of particular interest in interpreting this soil pattern are firstly, the uniformity of the environment with regard to features such as parent material and drainage condition, variations in which elsewhere largely dêtermine distribution, and secondly, the distinct association of stages in the pedogenic sequence with landscape position. These allow a geomorphological interpretation of each surface. The deep soils on the flat uplands represent, at least in part, weathering during the Ipswichian interglacial. Slope sites are thought to have been differentiated during the periglacial conditions of the last glaciation by solifluction of weathered surface horizons. The occurrence of stripes rather than polygons confirms this, and the coarse stony material lining the wider, dry valley floors is the product. An interpretation is shown in Fig.8.

Beccles Boulder Clay Soil Pattern

Sheet TM49 (Beccles) lies astride the lower reaches of the River Waveney where the Boulder Clay plateau, forming most of the surface in central East Anglia, is dissected into two additional landscape facets, the broad infilled valley floor of the Waveney floodplain, and between this and the plateau, a belt of lowland (Fig. 9). The plateau at 75 to 110 feet O.D. is flat or gently sloping. The floodplain, apart from a few low meandering micro-ridges which represent roddons or old stream channels, is a flat surface at about sea level. The lowlands between 0 and 75 feet O.D. are largely a weakly dissected terrace whose main surface lies between 25 and 40 feet.

The upland Boulder Clay has small chalk stones and is covered on central upland sites by thin Sands and

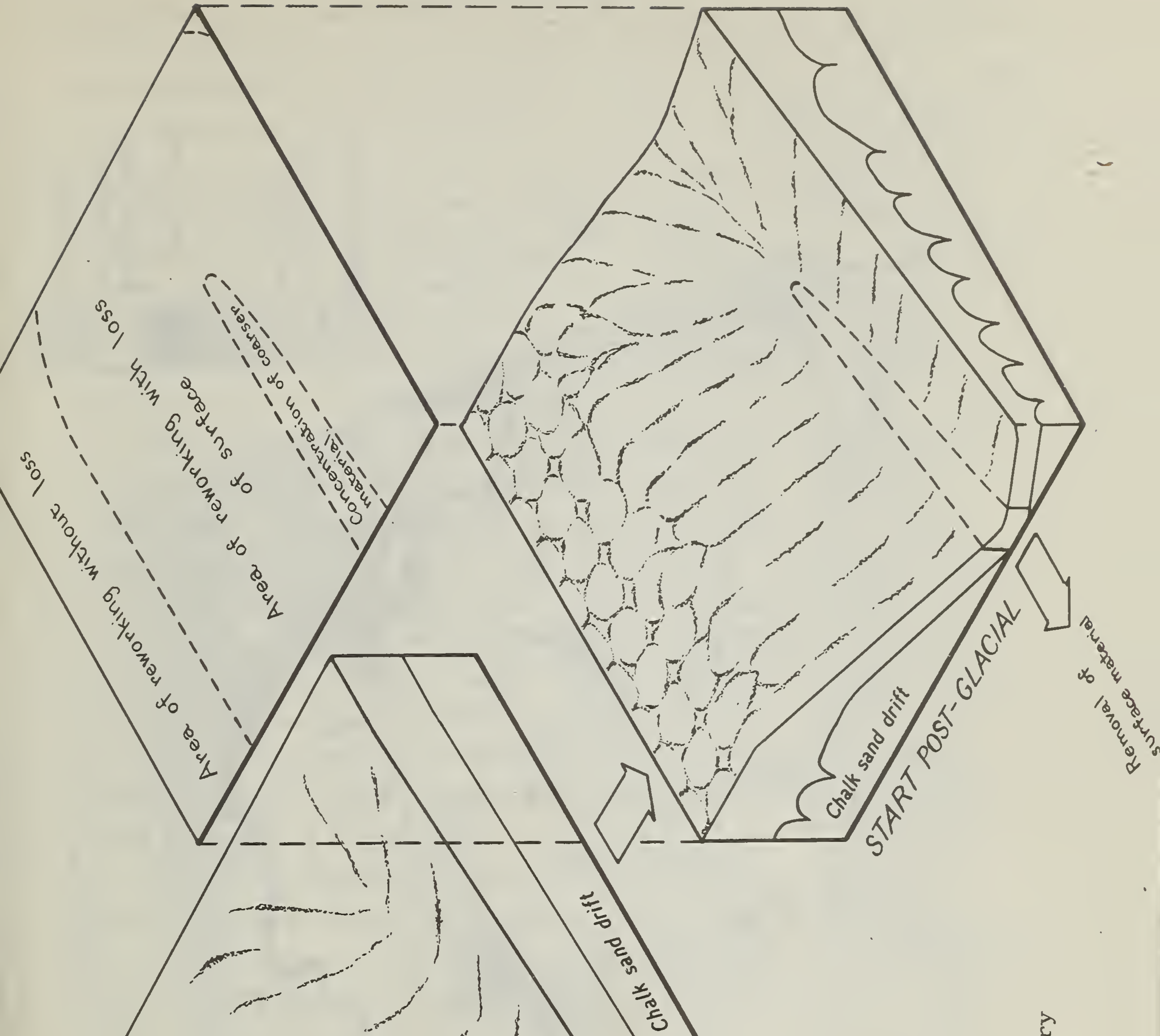


Fig. 8 Breckland Site History

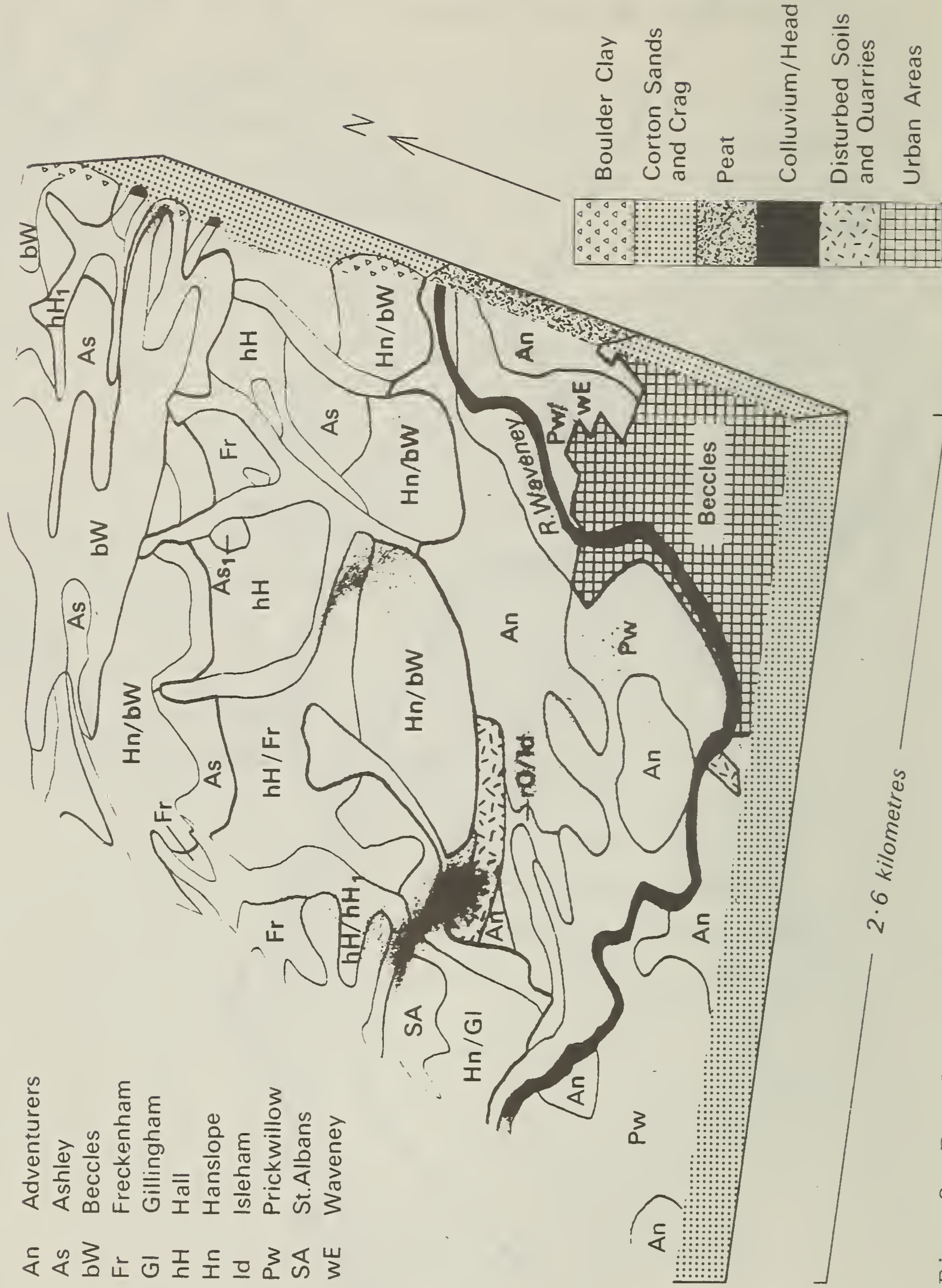


Fig. 9 Beccles - landscape and soils

Gravels. The lowlands are mainly Sands and Gravels, the Corton Sands and Crag deposits, outcropping from below the Boulder Clay, the break in slope at the point of outcrop being the boundary between the two facets. On terraces these beds can be capped by Valley Gravels. The river valley floor is infilled largely by organic deposits such as brushwood peats or nekron muds. Downstream this is almost completely covered by a raft of estuarine alluvium of silty clay texture a few metres thick. Both alluvium and organic deposits are capped by a thin skin of sedge-carr peat.

The morphology of the boulder clay soils is given in Figs. 10 & 11. They vary from sands to clays and are moderately well-drained to poorly drained.

Aldeby Series - This soil has six horizons and the lowest, the II Cg horizon of weathered boulder clay, is often well below auger depth. A noticeable feature is the sudden change from the surface sand to the underlying clay, which can occur at depths up to 2 metres. The discontinuity is shown in the horizon nomenclature by the use of Roman numerals, the decalcified gleyed clay in the lower profile being annotated IIBg..

The surface plough layer, the Ap, overlies pale-coloured sands partly eluviated of iron and designated Eg. Horizons of iron accumulation below are classified Bgfe and above, from lateral seepage across the site, as Agfe. The Eg or Bgfe overlies the II Bg horizon. In this soil the water table over a period of about four months between December and April rises spasmodically to within 25 cms of the surface and for long periods, if not continually, to within 50 cms. It is classified as imperfectly or poorly drained. The major soil processes are decalcification and gleying.

Beccles Series - These normally have five horizons but the lowest, the II Cg horizon, slightly weathered boulder clay, is seldom within auger depth. The surface Ap horizon has much sand and is a sandy loam or sandy clay loam.

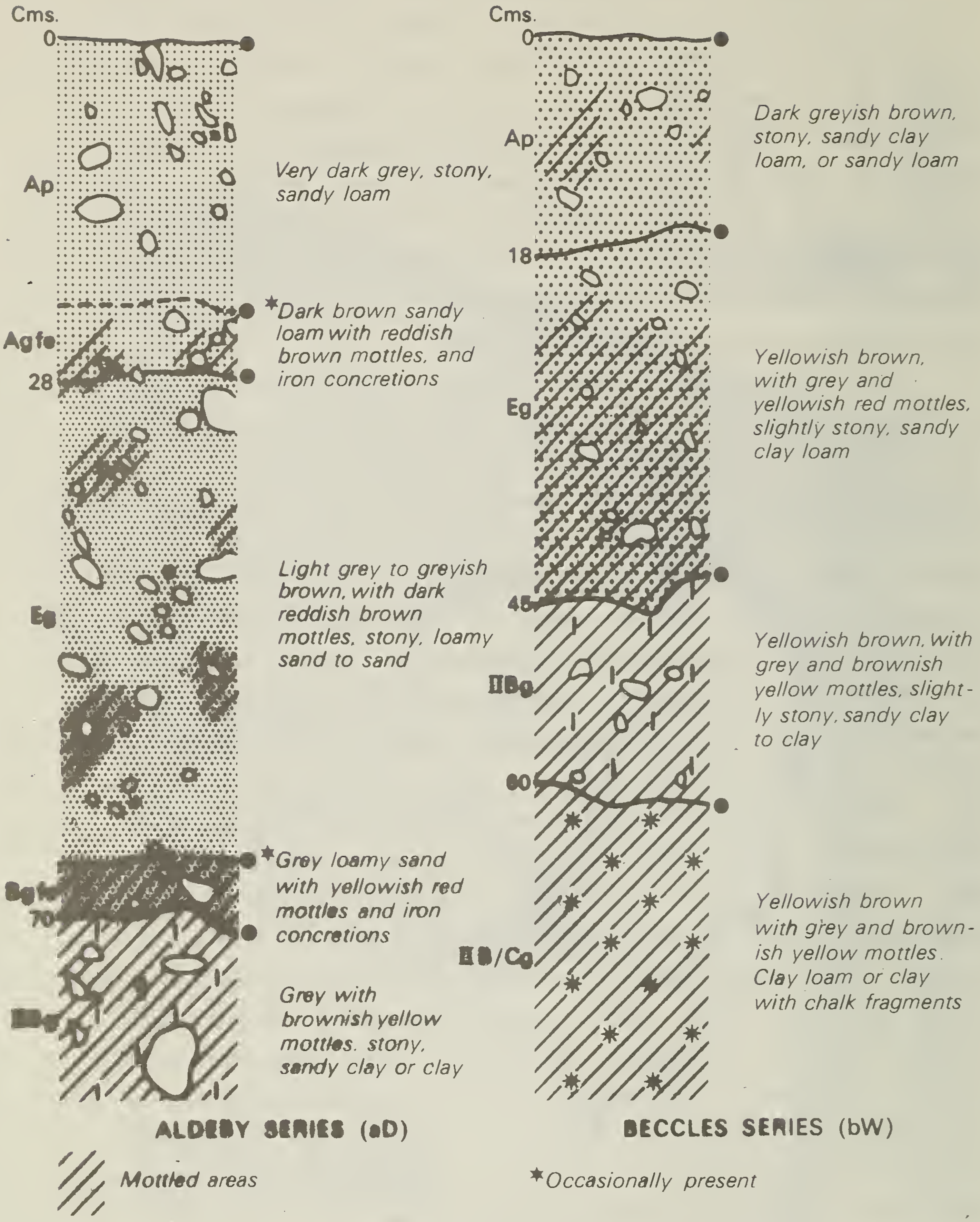


Fig. 10 Beccles - soil profile morphology (A)

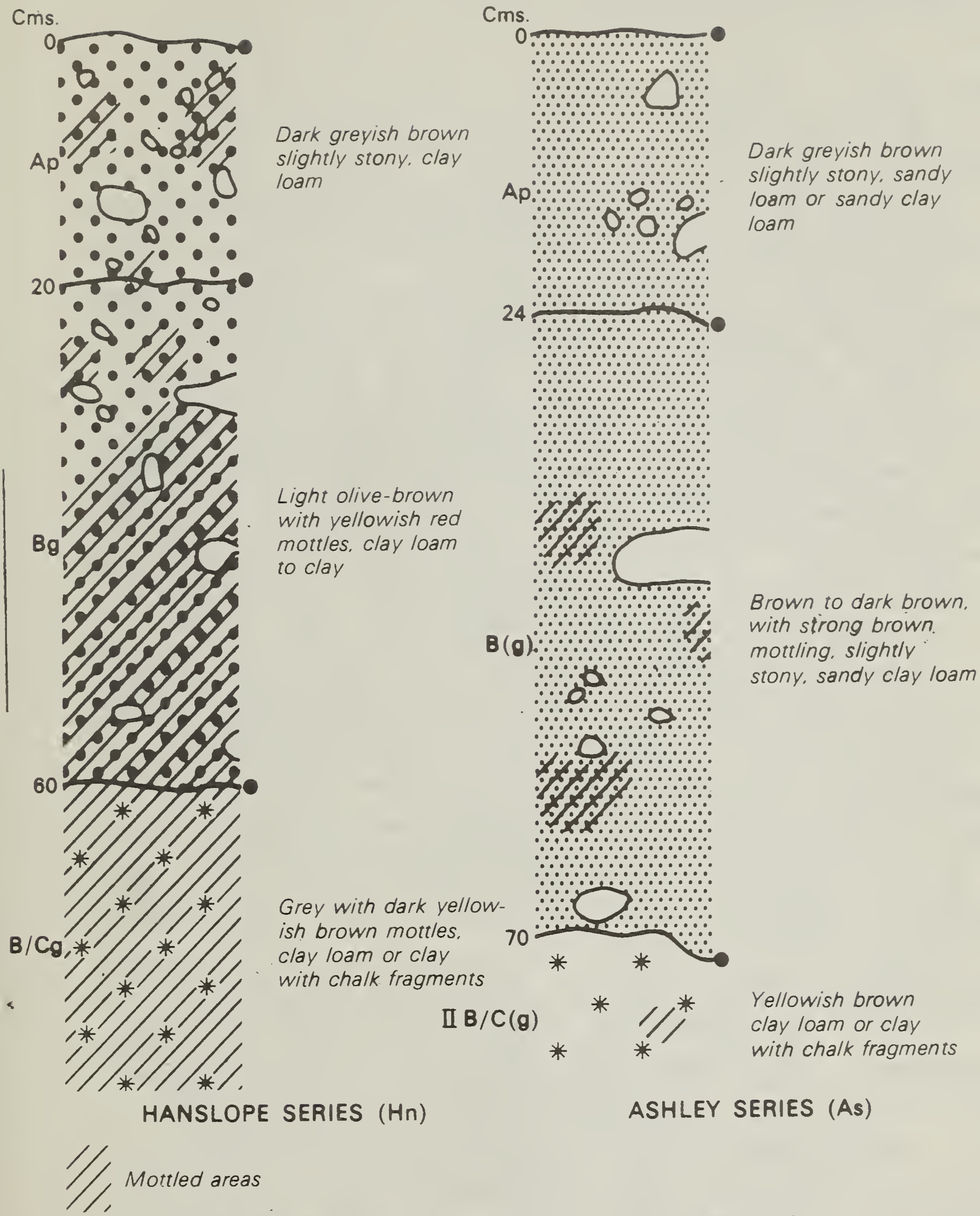


Fig. 11 Beccles - soil profile morphology (B)

The Eg horizon below is a pale-coloured mottled zone partly leached of iron. At about 45 cms it passes into the decalcified mottled boulder clay, the IIBg and at 60 cms to the II B/Cg horizon of mottled grey clay with chalk stones. The water regime is similar to that in the Aldeby series, but Beccles soils can be managed more efficiently, tile drains and ditches keeping the water table to below 50 cms. It is classified as imperfectly and poorly drained. The main soil processes are decalcification and gleying.

Hanslope Series - There are commonly four horizons but the Cg horizon of unweathered boulder clay, is well below auger depth. Deep borings show mottling on structural faces to below 3 metres. The surface horizon, the Ap is a clay loam or sandy clay, and much less sandy than in the Aldeby, Beccles or Ashley series. Below this is an olive coloured, mottled, decalcified well-structured clay or clay loam, the Bg horizon, changing at about 60 cms to a grey, mottled, clay with chalk stones, the B/Cg. The soil is apparently less affected by the rise in the winter water table than those described earlier, the gently sloping site and the better structured subsoil allowing lateral seepage so that the water table seldom rises to within 50 cms of the surface. Tile draining and moling are effective and the soil is moderately well drained or imperfectly drained. The main soil-forming processes are decalcification and gleying.

Ashley Series - This soil, like the Aldeby and the Beccles, has a textural discontinuity, and three horizons can be recognised. The plough layer, the Ap, is over a slightly mottled decalcified sandy loam or sandy clay loam, the B(g). Below about 70 cms is slightly mottled slight weathered boulder clay, the IIB/C(g) horizon. There is, apparently, no winter water table. On sites with Ashley soils the boulder clay is a shallow cap only 1 to 2 metres deep over permeable sands and gravels, and the clay is apparently sufficiently fissured to allow vertical seepage

of drainage water. The soil is moderately well drained. The soil-forming processes are predominantly decalcification with slight gleying.

These four soils are presented in Fig. 10 in the order in which they occur from the centre to the edge of the boulder clay uplands. Differentiating features are surface sand in the Aldeby, the absence of this in the Hanslope, and the mixture of sand with the clayey substrata in the upper horizons of the Beccles and Ashley. The Ashley series with permeable substrata and no winter water table is moderately well drained. In the other three soils, the thickness of the boulder clay is sufficient to form an impermeable substratum, preventing vertical seepage and supporting a winter water table. In the Hanslope, however, the effect is ameliorated by lateral seepage on sloping sites through the well-structured subsoil. In contrast to the Breckland, these differentiating features are here due to variations in lithology rather than the soil-forming process, which is similar for three of the soils.

The general distribution of three of the soils in the upland landscape facet is shown in Fig. 9, the area just north of Beccles. The sequence from central to perimeter sites on the uplands is Beccles, Hanslope, and Ashley series. Aldeby soils occur slightly higher to the north. As in the Brecklands, local distribution is more complex, and Fig. 12 shows the scale of variation. The site is a boulder clay crest overlaid by shallow surface sands and gravels. Trench A is on the flat crest, B down slope and C across the slope. It is worth comparing these somewhat regular contortions with those in the Breckland stripes and polygons. Fig.13, from Trench C, shows Aldeby and Beccles soils adjoining, Beccles soils occurring where the boulder clay is almost immediately below the plough layer. Such a site is mapped as a compound unit of Aldeby and Beccles. Both the magnitude and the frequency of boulder clay contortions is of the order of two metres. This is extreme, and a more subdued variation, with a vertical

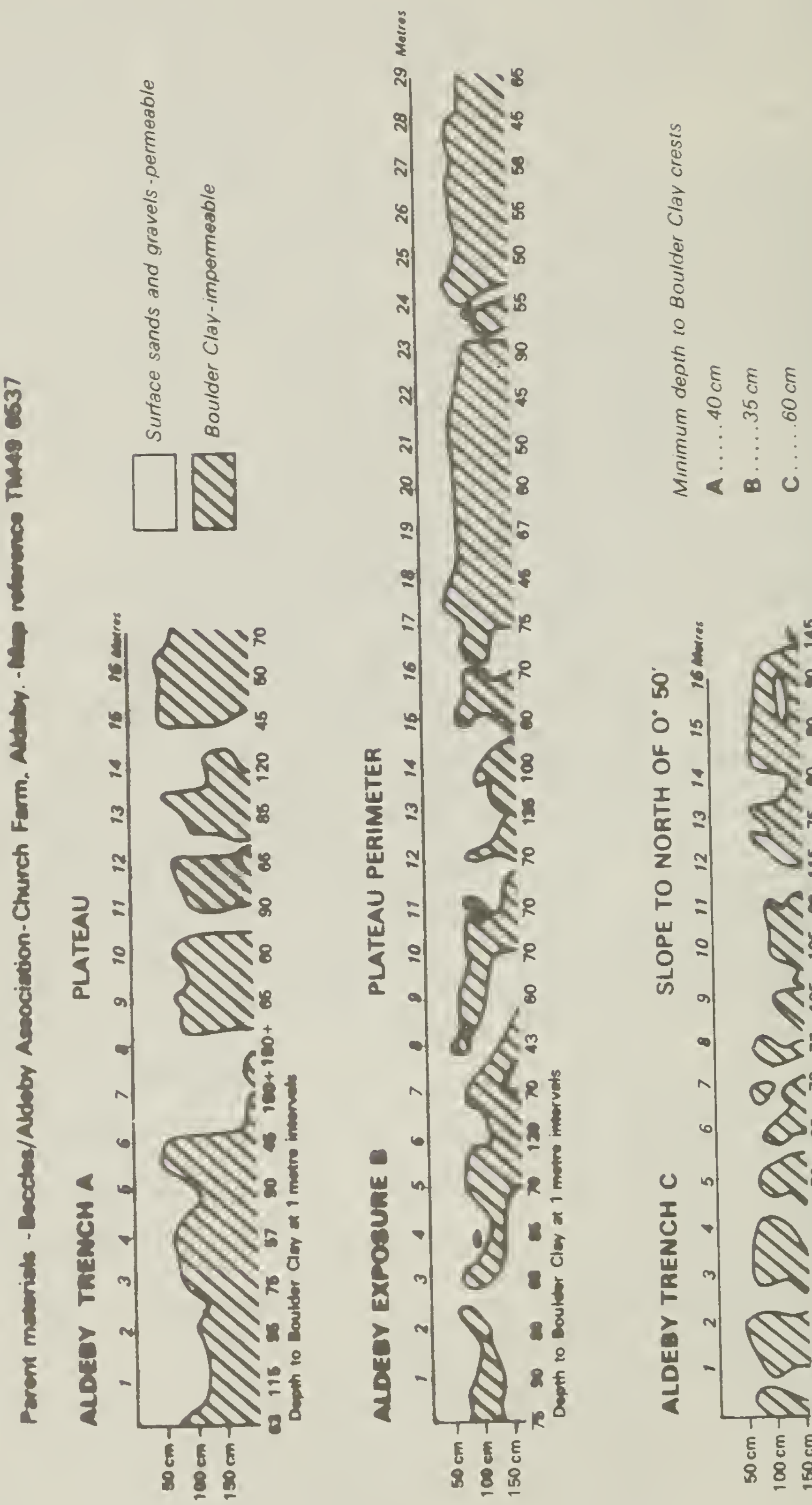


Fig. 12 Beccles - distribution of surface gravels and boulder clay

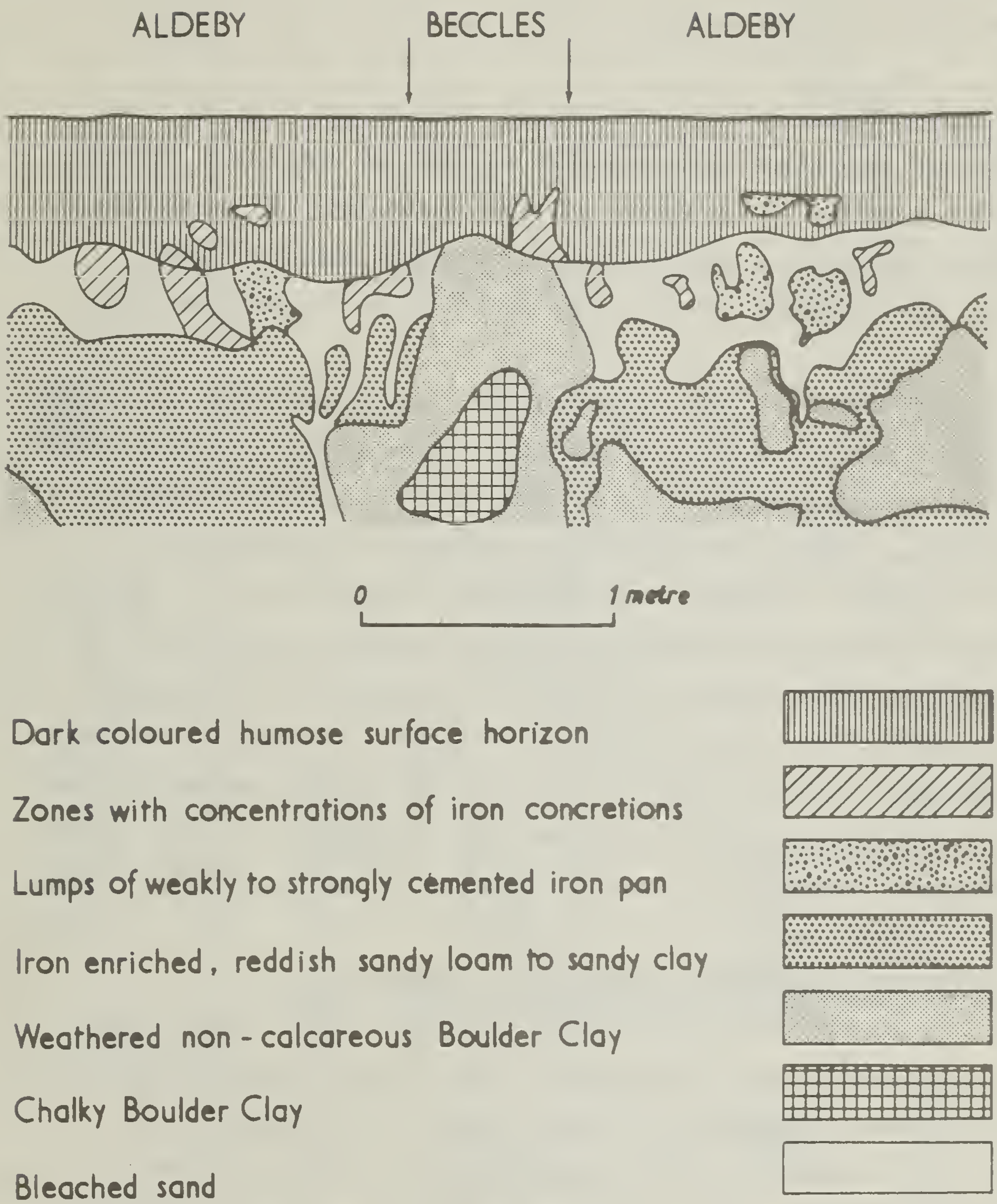


Fig. 13 Beccles - soil pattern in Beccles/Aldeby unit

magnitude of about 10 cms, and a frequency of about two metres occurs on sites where shallower soils with a clay loam or sandy clay plough layer (Hanslope series) alternate with soils with surface textures of sandy loam or sandy clay loam over depressions in the boulder clay (Beccles series).

Mapping units on the plateau, shown in Fig.9, are compounded of Beccles and Aldeby soils on central sites, the Beccles series over most of the plateau, a compound unit of the Beccles and Hanslope towards and at the perimeter, and Ashley series on the crest of projecting spurs.

This pattern can be related to three related factors: the distribution of surface sands, apparently eroded from all but central plateau sites, and particularly from gently sloping sites towards the plateau perimeter; vertical seepage through the boulder clay where it thins out at the plateau perimeter, and frost heaving with the maximum effect where the textural contrast is greatest. Changes in the first two factors are on a scale of several hundred metres and are seen on 1:25,000 scale maps in the sequence of mapping units across the plateau. The short range scale of the third factor can only be indicated by compound mapping units.

Cromer Ridge and Boulder Clay Soil Patterns

Fig. 14 shows a north-south section from the ridge crest to boulder clay lowland to the south, the boundary between the two landscapes occurring at Matlask. On the ridge the substrata are predominantly Pleistocene Sands and Gravels, and in the southern lowlands a brown non-calcareous boulder clay morphologically resembling the Norwich Brickearth. In both landscapes these materials are covered by thin loamy drift probably of aeolian origin. The textures of all three materials are shown in Fig.15: the gravels have less than 10 per cent clay and less than 15 per cent silt; the brown non-calcareous boulder clay, a clay content between 15 and

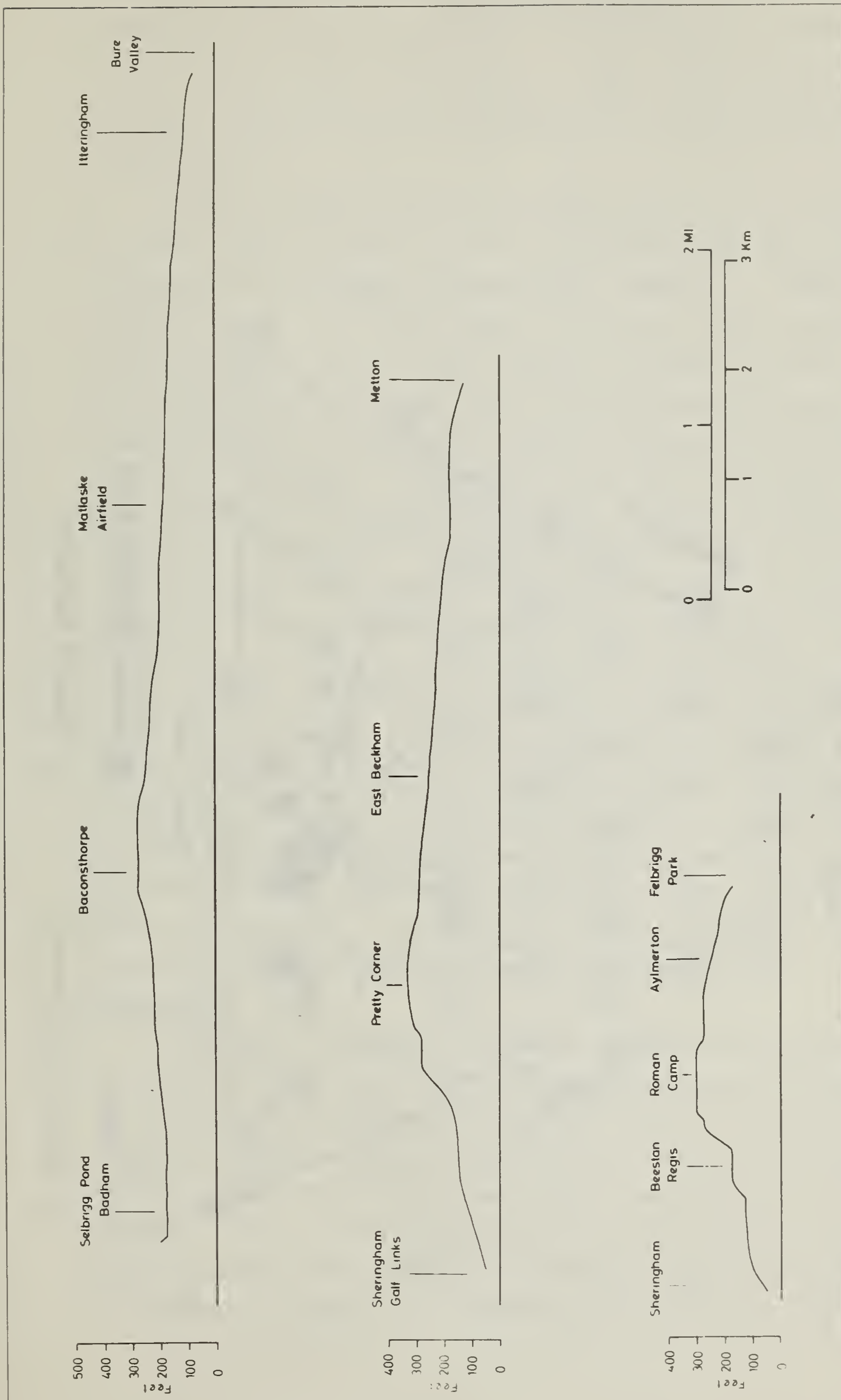


Fig. 14 Cromer Ridge - relief sections

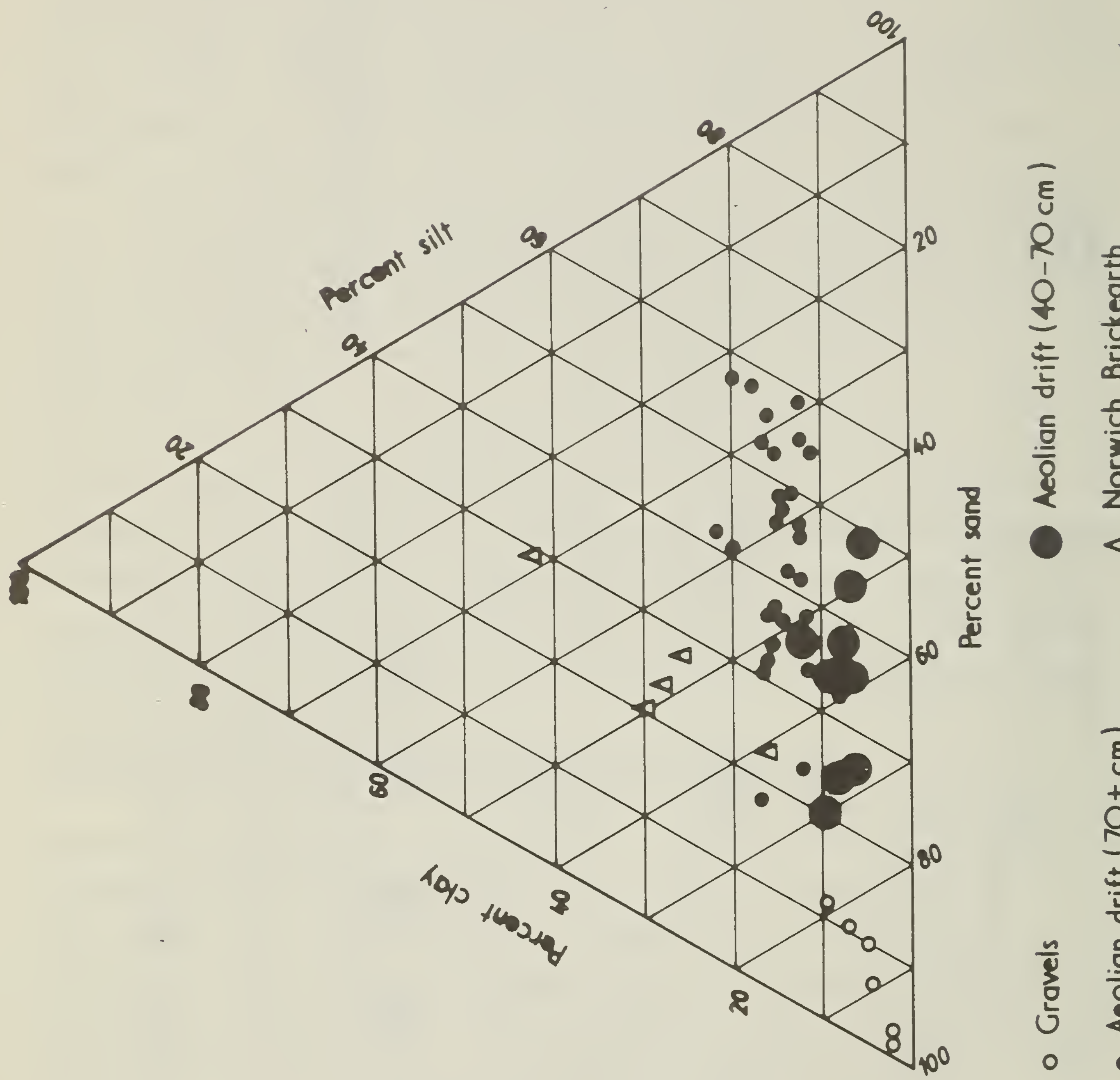


Fig. 15 Cromer Ridge - mechanical composition of Drifts

30 per cent, and a silt content between 20 and 30 per cent; and the covering aeolian drift less than 20 per cent clay and 20 to 60 per cent silt. The texture of this covering is related to its thickness. Thin deposits contain less than 10 per cent clay and less than 50 per cent silt, and thicker deposits 10 to 20 per cent clay and up to 60 per cent silt.

Fig. 16 shows their distribution in the landscape. On the ridge, aeolian drift is absent from the steepest slopes with southern and western aspects. Shallow deposits, 40 to 70 cms thick, occur on flat crests, and deposits more than 70 cms thick on valley floors and on the gentle lower slopes with northern and eastern aspects. On Boulder Clay Lowlands, shown in Fig.17, the pattern is broadly similar. Additional facets are shallow sand and gravel caps on interfluve crests, terraces and peat-filled floodplains. Excluding these latter sites all soils both on the Cromer Ridge and in the Lowlands to the south are well drained or moderately well drained and are Brown Earths.

On bare ground in Spring the pattern on the Cromer Ridge is sometimes shown by the colours of the surface soil, darker tones indicating moister and deeper more silty aeolian drift with fewer stones. Later in the season the pattern is reflected by crop growth, in dry years the best growth occurring on valley floors with poorer growth on slopes. In wet years the growth pattern is reversed, cereal yields being higher on slopes.

Discussion

The soils and soil patterns described illustrate the two purposes of soil survey; classification and mapping. The basic unit in classification, the soil series, is defined by the nature and intensity of the soil-forming process, the texture of the parent material and the water regime. On the Breckland drift, with uniform parent material and water regime the series can be regarded as consecutive stages in a theoretical soil development

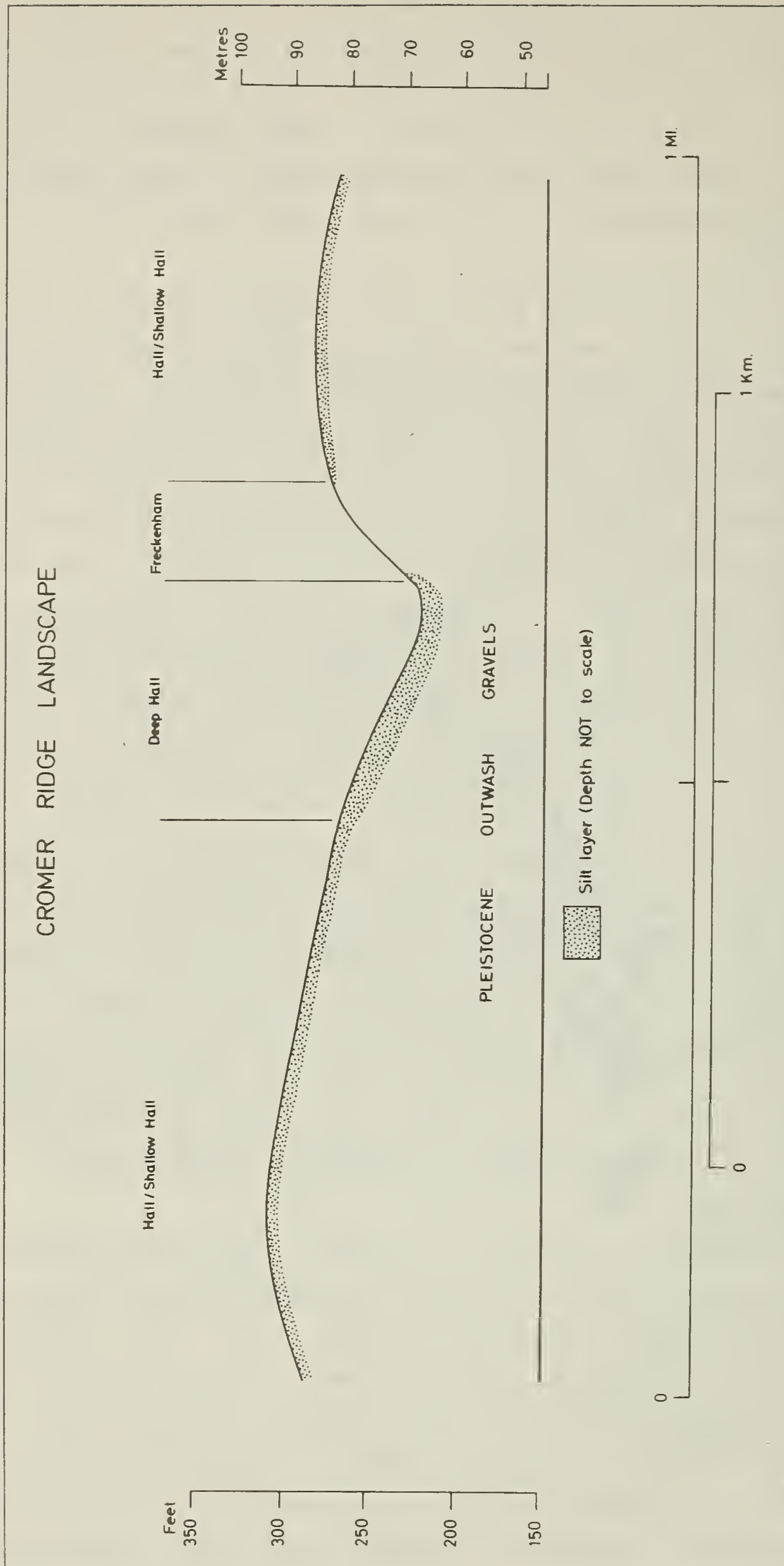


Fig. 16 Cromer Ridge - soil pattern

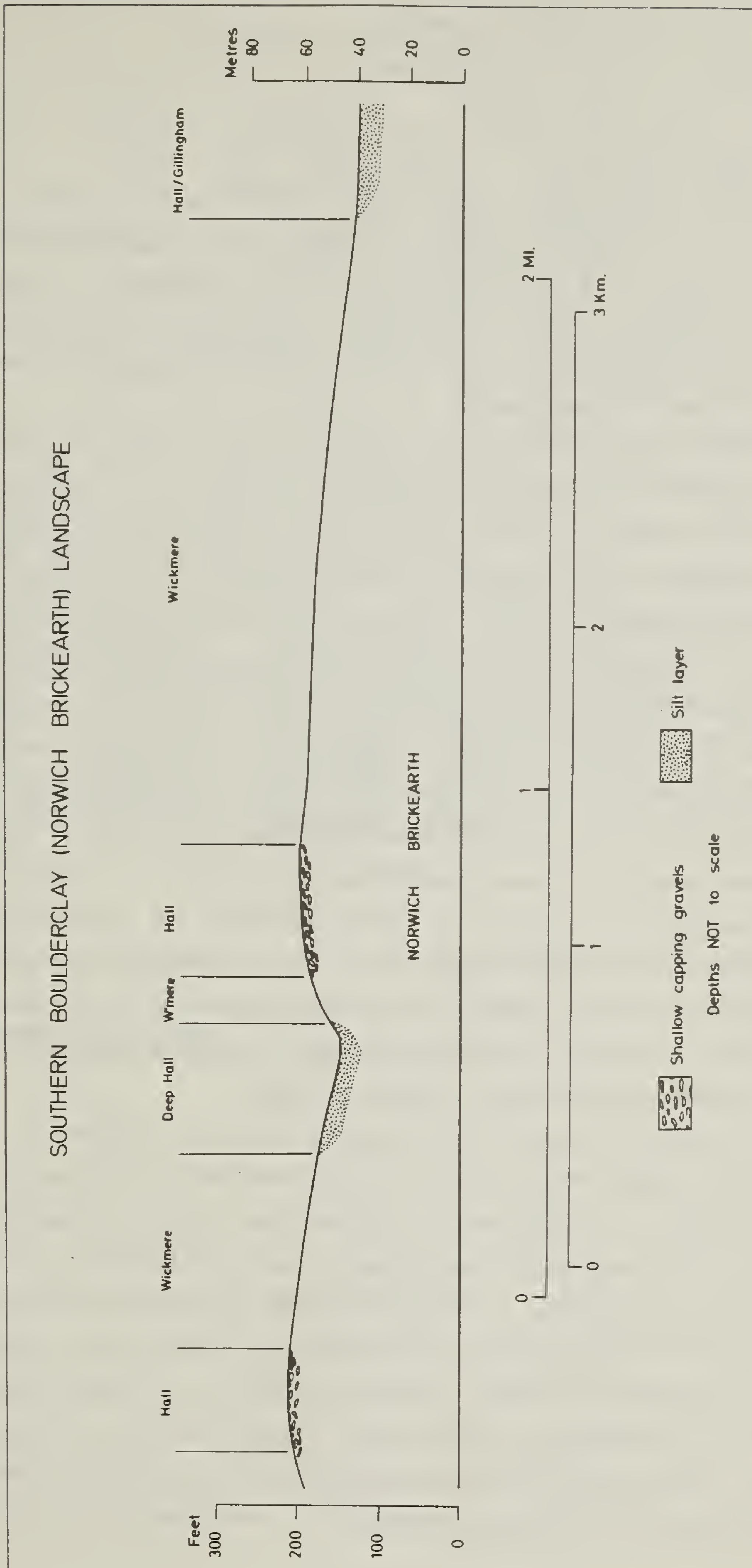


Fig. 17 Boulder Clay Lowlands - soil pattern

sequence. On the Cromer Ridge where the water regime and soils-forming processes do not vary, series are characterized by varying depths of aeolian drift over gravels or boulder clay. At Beccles, series on Boulder Clay are differentiated by depths and texture of surface drift, in this case sands and gravels, with the additional factor of a variable water regime due to permeability of the boulder clay below and lateral seepage. Thus in establishing a classification for a locality distinctions are made according to the local importance of one other of the three components.

The distribution of soils in the three areas shows that pattern occurs at different scales. Small-scale variation such as the sand and gravel-filled pockets in the boulder clay surface round Beccles or on the Breckland stripes are recorded on 2½ inch maps by compound units. Large-scale variation, occurring across individual landscape facets, at intervals of several hundred metres, are shown by the sequence of mapping units, the Aldeby, Beccles, Hanslope and Ashley sequence at Beccles and the Worlington unit and Worlington/Santon compound sequence unit on the Breckland uplands. A still larger scale pattern is seen in the sequence of facets in any landscape, and the largest in the landscapes themselves. Examples in East Anglia of such landscapes are the Fens, the Chalk Scarp, the Brecklands, the mid-Anglia Boulder Clay Plateau, and the Cromer Ridge.

A 1:25,000 sheet is mapped in two stages: reconnaissance when soil to landscape relationships are established, a taxonomic legend set up, and mapping units chosen; and detailed mapping, when boundaries between units are located. Such boundaries can be visually associated with relief features or found by a regular grid of auger borings, which at the 1:25,000 scale are often at 200 metre intervals. The value of units thus mapped stems from the principles of soil distribution established by reconnaissance. In practice the principles,

and consequently the mapping units and boundaries, are often further developed during the detailed stage. A procedure used earlier for reconnaissance in this region employed transects across relief features with a sampling interval of less than 200 metres. On sheet TM31 (Horning), where reconnaissance has just been completed, the sampling system consisted of 25 major sampling centres spaced regularly at 2 kilometre intervals, each consisting of four subsidiary sampling centres at the corners of a square of 200 metre side, each in turn having four sampling points at the corners of a square of 20 metre side. In such 'nested' sampling the 2 kilometre interval is designed to identify landscape facets, the 200 metre interval picks out variation within facets and the 20 metre interval establishes local variations like those in Breckland stripes. Profile data recorded in this unbiased way can be treated statistically and sorted into groups of similar profiles, taxonomic units or individual soil series. Series in particular parts of the landscape can also be grouped into mapping units.

Submitted July 1970

this zone.

These noted are contributed on the chance that the information may be useful in further research on this subject.

Submitted March 1970

TEMPORARY EXPOSURE IN THE DRIFT NEAR CROMER

P. H. BANHAM

Introduction

Excavations in connection with the building of the Clifton Park housing estate on the Runton Road at Cromer have revealed an interesting temporary exposure in deformed glacial and glaci-fluvial deposits. The precise location is on the northern flank of a small hill (+150' OD, named Howard's Hill on the 6" map) near the western boundary of the Urban District of Cromer. At the moment the section lies parallel to and within 20 metres of number 81, Clifton Park (TG 209421). More houses are to be built in the immediate vicinity, however, and it is understood that the exposure will be at least partly obscured in the near future.

Description of the section

These observations were made at the end of July and during mid-September 1970. The exposure (Fig.1) was then 60 metres in length and up to 4 metres in steep to vertical section. The succession would seem to be as follows:-

3. Gravel and Sand	2m	(maximum vertical
2. Yellow Sand	3m	thicknesses are
1. Chalky Till	3m	given).

1. The Chalky Till has a small outcrop in the central part of the section, where its presence is due to disturbances of the beds. The larger part of this outcrop consists of very chalky, white till with few flint pebbles; the remainder is cream to brown in colour, less chalky, and contains more numerous erratics, mainly rounded, black flint pebbles (200 mm and under). Both these lithologies may without difficulty be matched within the Contorted (Marly) Drift and its included chalk rafts exposed in the nearby and generally lower coastal cliffs.
2. The Yellow Sand is generally coarse and cross-bedded,

"IRON MINERAL GEODES" OF SUFFOLK

H.E.P. SPENCER

In nearly half a century of observations in Suffolk sands and gravels, inevitably some familiarity is gained with the varieties of ferruginous concretions, etc., which occur with some frequency in most pervious deposits such as sand and gravel, including the Red Crag. However with less experience of Norwich Crag no comment can be made.

An important fact has to be taken into consideration, which is drawn from archaeological observations, i.e. iron nails from fourth century Roman villa sites and the clench nails from ship burials of the dark ages, provide a clue to the hollow found in a great proportion of the geodes. In these, it has been found that the original iron, during the process of oxidation, has migrated outward, concreting the surrounding matrix of sand or gravel, leaving a hollow mould in the size and form of the object.

So far as the Red Crag is concerned, as the level of the sea spread inland, the London Clay, with pyritous nodules and pyritised wood in large quantities, was eroded and in some local areas totally destroyed. Since the presence of London Clay Crustacea and other fossil remains which became incorporated with the other derived materials in the Basement Bed prove this destruction, it is obvious that other solid objects would similarly be included in the new formation. It is also noteworthy that areas of the Clay were full of fine particles of pyrites, or marcasite. This was probably disseminated throughout at least part of the Crag. The structure of the lower part of the Red Crag shows that the beds were deposited, then removed by currents and re-deposited, which must have resulted in the redistribution of matter in the older parts of the formation.

A number of geodes which have been examined, have been found to contain a yellow powdery residue somewhat similar

in appearance to the residue resulting from the decomposition of pyritised wood when the iron sulphate is washed away. This residue has not been analysed, but such analysis should be illuminating.

Other geodes, not from Crag, are completely hollow except for column-like structures linking the lower and upper surfaces, these often are lined with a glossy black coating resembling a form of pyrolusite.

The Gipping outwash gravels in south east Suffolk contain a great quantity of derived fragments of Crag shells and very rarely, bits of sub-Crag bones, a result of the destruction of an area of Red Crag northward of the mapped limit. Some of the geodes could possibly be derived from that Crag.

The suite of erratic rocks, notably at Creeting St. Mary in the Gipping Valley, is similar in both the outwash gravel and the overlying Gipping Till. Boulders of basaltic rocks with spheroidal weathering have been obtained from both, others are Jurassic limestones from Lincolnshire and garnetiferous schist from Scotland. Amongst the Jurassic materials are masses of limonitic material full of moulds of shells.

During the nineteen-twenties a Crag pit on Bixley Heath, Ipswich, had an interesting lenticle in the section below 8 to 10 feet of decalcified Red Crag with stalactite-like concretions formed around roots with moulds of shell fragments. The lenticle was a solid mass of limonitic rock full of moulds of large bivalves.

At no time has any concretion been observed which had the appearance of having been formed by the concentration of ferruginous matter to form a concretion.

In the Westleton Marine Shingle Beds at Holton, below the water table, there is a pyritised zone with shells and impregnated fossil wood with some bones and teeth of Villafranchian fauna. From the evidence at this site it seems probable that lowering of the water table would eventually result in the limonitisation of

the laminae dipping E to NE at up to 20° where undisturbed.
3. The Gravel and Sand overlies the Yellow Sand sometimes with evidence of marked channelling. Flint boulders of "cannon-shot" type are common.

The entire section exhibits minor undulations and other disturbances, although the only significant deformation involves the Chalky Till and those parts of the other beds which are immediately adjacent. A horst-like mass of Chalky Till has been emplaced into the overlying Yellow Sands. The western till/sand contact is deformed about open folds of very variable plunge, although the largest of these plunges approximately west at 5°, and has a nearly horizontal axial plane. Despite this folding it can be seen that the bedding of the Yellow Sands is approximately co-planar with the surface of the Chalky Till. This suggests that the original, sedimentary, till/sand junction is here little disturbed.

The eastern side of the Chalky Till mass, by contrast, shows a nearly vertical, smooth, planar contact with the Yellow Sands which have suffered local dragfolding. The overall impression is that of a fractured diapir and/or a minor upthrust mass of till.

That such upward emplacements of till may be common in this area is indicated by the apparently haphazard and rapid alternation of sand and chalky till demonstrated and described to me by the men who had dug the foundations of the houses within half a kilometre to the north (i.e. approximately down to the 100' contour).

Discussion

There would seem to be little doubt that Chalky Till is a disturbed portion of the local chalky variety of the Contorted (Marly) Drift. Further, on the grounds of general lithological similarity and the geomorphological continuity of Howard's Hill with the main "Cromer Ridge" to the south, the Yellow Sands and Gravel and Sand can be accepted as part of the variously named (Cromer) Ridge

or Briton's Lane Gravels.

The well-known Briton's Lane pit is within 4 kms to the west of Howards Hill and it is of some interest that it, too, shows chalky till upthrust into the sands and gravels (immediately south of the pit offices and works).

The full implications of all the available evidence can not be discussed here. In brief, the Howard's Hill exposure confirms the conclusion that at least one period of deformation, probably glacially initiated, but not necessarily glacial tectonic, occurred after the deposition of the Ridge Gravels.

Submitted October 1970

Fig. 1

REPORT OF A FIELD MEETING IN BRECKLAND, 20 SEPTEMBER 1970

C.E. RANSON

The meeting began at East Wretham Heath (TL 912884), a Reserve of the Norfolk Naturalists' Trust.

A description was given of the Great Ouse River Authority's ground water pilot scheme. This is being undertaken to see if it is possible to abstract water from the Chalk aquifer in such a way that percolation from rainfall and other surface water will provide continuous replenishment of the Chalk aquifer after the water table in the chalk has been lowered 7m by pumping.

Since this is a pilot scheme, the whole exercise is being closely monitored. The area where water is being extracted is confined to about 70 km^2 in the parishes of Great Hockham, Bridgham, East Harling, Quidenham and Shropham, and within the catchment of the River Thet. Observation boreholes, river and mere gauges and meteorological stations have been established to record the changes caused by the abstraction and to relate them to meteorological conditions. A similar series of observations is being made in an area of comparable size centred about 8 km to the north west and including parts of the parishes of Tottington, Thompson, Merton, Stamford, Stow Bedon, Sturston and Buckenham Tofts in the catchment area of the River Wissey.

The experiment is to run for seven years. If it is successful, it is possible that the practice will be extended to other parts of the Chalk in the River Authority's area.

The pilot scheme has required the sinking of a great number of boreholes to the Chalk. The new information on the thickness and nature of the drift overlying the Chalk has yet to be interpreted fully, but it is apparent that there is a great deal more boulder clay in thickness and extent than was formerly supposed.

East Wretham Heath lies between the pilot area and the control area. A borehole put down in 1968 at TL 908884 on the higher land between Langmere and Ringmere, as a supplementary observation well to give information on the water levels of the two meres, showed the following succession:

Lithology	Thickness	Depth of base from surface
Sandy soil	0.35m	0.35m
Sandy subsoil	0.40m	0.75m
A mixture of sand, chalk, pebble and chalk clay becoming gravelly toward the base: Chalk Boulder Clay	c. 15m	c. 16m
Chalk	c. 9m	c. 25m

Water was found at 6m down from the surface and also in the Chalk. The upper water level was approximately the same as the level in the meres.

This borehole showed that in spite of the observed correlation between water levels in these meres and the Chalk (Jones & Lewis 1941) there is a need to reconsider the nature of this relationship. As the pilot scheme progresses, more information should become available on the shape of the boulder clay surface and the connection between rainfall and the water tables of the boulder clay and the Chalk.

As a result of the recent excavations of trenches for pipe lines across the Breck, a number of sand-filled depressions in the boulder clay have been noted. These depressions have the approximate lateral dimensions of some of the smaller meres, though their vertical extent is not known. They appear to be periglacial features and it maybe that some of the meres are of similar origin; but detailed work would be necessary to substantiate this or any other observation on the origin of the meres.

The second feature visited was the area of stone stripes on Thetford Heath National Nature Reserve.

Fortunately part of the Heath near the road at TL 849796 has had its topsoil removed so that it is possible to see clearly the parallel rows of stone and chalk alternating with rows of sand. Where the topsoil has not been removed the rows of stone and chalk support a grassy vegetation and the deeper, less calcareous, sandy soil carries a strong growth of heather (*Calluna vulgaris*), thus making it possible to detect striping on vegetated heath.

This convenient example is one of many throughout the Breckland and these, with other types of patterned ground due to periglacial conditions, are described in Watt (1955), Watt, Perrin and West (1966), Williams (1964) and West (1968, chapter 5).

The third visit was to the High Lodge site, Mildenhall (TL 738754) which is owned by the Forestry Commission but leased to the Suffolk Trust for Nature Conservation. This former gravel pit has been well known for its Palaeolithic implements for over 100 years. It was re-excavated by G. de G. Sieveking of the British Museum during the last decade and the site has now been systematically recorded and the deeper holes filled in. The present exposures show the upper part of the sequence: a thin layer of chalky clay, underlain by sands and gravels and chalky gravels, lying on a series of sands, silts and clays, which in turn lie on a calcareous boulder clay. Many Palaeolithic implements, especially handaxes, came from the upper part of the series of sands, silts and clays. At the present time the author has no detailed information on the outcome of the archaeological and geological studies made at the site.

The fourth visit was to Mr. and Mrs. Rumbelow's disused chalk pit at West Row (TL 681753). Here the Lower Chalk shows the development of a pink horizon, a half to one metre thick. The intensity of the coloration varies vertically and horizontally. One fossil brachiopod and a probable trace fossil were found. This section needs a detailed description.

The final visit to the Lark Valley between Barton Mills and Lackford demonstrated the series of partially active sand dunes on either side of the A1101 from TL 740740 to TL 770733 and the gravels on Rampart Field, West Stow (TL 787716). Funnell (1955) has described the geology of this and surrounding areas in some detail.

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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 20

CONTENTS INCLUDE:

Origin of North Sea – Geology in Education – Zones of Gipping Valley Chalk – Forest Bed Horse jaw – Field meeting reports – Bibliography supplements.

BULLETIN of the GEOLOGICAL SOCIETY OF NORFOLK
No. 20 September 1971

Editor: R. S. Joby
116 Gowing Road, NORWICH, NOR 40M

EDITORIAL

In this, the second issue of the Bulletin in its new format, we have articles on the origin of the North Sea, Geological education, and the Chalk in Suffolk.

The growth of Geology as an academic subject, in all types of educational establishment, was remarked on in the recent talk by Mr. Colin Ranson ("Geology for Young and Old" - Castle Museum, March 25, 1971), and our present contributor, Mr. Hywel Evans, who lectures at the Norfolk College of Arts and Technology, King's Lynn, outlines methods and progress there. It is hoped in future issues to publish articles on other aspects of Geology and education.

Bulletin No.21 will be issued in the Spring of 1972. Contributions should be sent to me as soon as possible, and no later than January 31, 1972.

Will contributors please note that manuscripts are acceptable in legible handwriting, although typewritten copy is preferred. Illustrations intended for reproduction without re-drawing should be executed in fine, dense black ink line. Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations before reproduction, should fit within an area of 225mm by 175mm; full use should be made of the second (horizontal) dimension, which corresponds to the usable width of the page in the printed version, but the first (vertical) dimension is an upper limit only.

R.S.J.

THE ORIGIN OF THE NORTH SEA
(a summary of the Presidential Address for 1969, delivered January 15, 1970)

B. M. FUNNELL*

Introduction

The North Sea is a shallow epicontinental sea bordering the North Atlantic ocean, with which it connects broadly to the north, and narrowly to the south via the Straits of Dover. Over most of its southern half it is less than 50m deep, and even in its northern part does not generally exceed 200m in depth.

The North Sea occupies a structural basin known as the North Sea Basin, which has existed in some form or other, and contained shallow seas of one form or another, for some 270 million years, i.e. from the Permian period onwards. During this time nearly 5,000m of sediment have accumulated in places in the Basin, compared with which the depth of the present sea is insignificant. At no time has the depth of water in the North Sea Basin approached 5,000m. Therefore the history of the Basin has clearly been one of progressive subsidence, leading to occupation by a succession of shallow seas of different types, culminating in the North Sea of the present-day. In the following account the origin of the North Sea is traced from the inception of the structural basin at the end of the Carboniferous (270 m.y. BP) to the definition of more or less the present form of the North Sea at the beginning of the Tertiary (65 m.y. BP). (In the sequel: 'The History of the North Sea' - Presidential Address for 1970, this story will be brought up to the present-day.)

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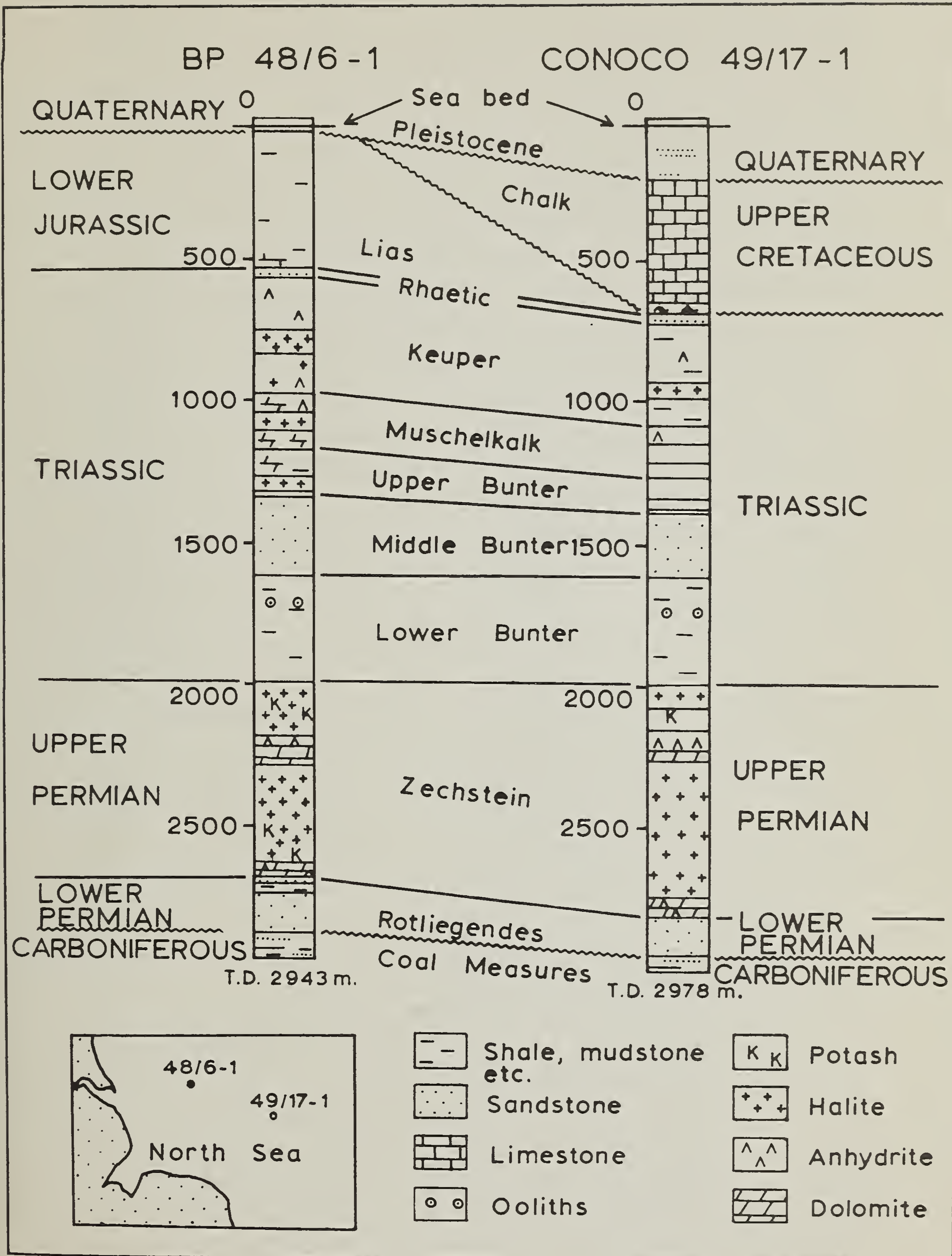
Fig. 1. Succession in the North Sea Basin off Norfolk (after Kent and Walmsley 1969)



BP 48/6-1
CONOCO 49/17-1
QUATERNARY
0
Sea bed
0
Pleistocene
QUATERNARY
LOWER
JURASSIC
Chalk
UPPER
CRETACEOUS
500
Lias
500
Rhaetic
Keuper
1000
1000
Muschelkalk
TRIASSIC
Upper Bunter
TRIASSIC
1500
Middle Bunter
1500
Lower Bunter
2000
2000
UPPER
PERMIAN
Zechstein
UPPER
PERMIAN
2500
2500
LOWER
PERMIAN
CARBONIFEROUS
Rotliegendes
Coal Measures
LOWER
PERMIAN
CARBONIFEROUS
T.D. 2943 m.
T.D. 2978 m.
48/6-1
49/17-1
North Sea
Shale, mudstone etc.
Sandstone
Limestone
Ooliths
Potash
Halite
Anhydrite
Dolomite

Coal Measures times

At the time when the Coal Measures of the British Isles and N.W. Europe were accumulating, a vast expanse of deltaic and paralic (i.e. coastal) swamps existed right across the North Sea from the eastern United States (now separated from Europe by the Atlantic Ocean) to Poland. This region was bounded to the north by the Caledonian mountain chains whose remnants are found in Newfoundland, Scotland and Scandinavia, and to the south in part by open sea. Out of the swampy plains stood "islands" of Precambrian and lower Palaeozoic rocks, notable among which was the East Anglian-Brabant Massif, extending from the Midlands to Belgium. The rocks of this massif still exist only a hundred or so metres below the surface of parts of East Anglia. Nothing in this distribution of land and sea gives any indication of the ultimate site of the North Sea Basin, which was about to be delineated.

Towards the end of Coal Measures times mountain-building movements erected the Hercynian mountain chains running east-west through S.W. England and Brittany. A minor, though none-the-less substantial effect of these earth-movements was the raising of the anticlinal north-south axis of the Pennines - with complementary depressions on either side now forming the sites of the Irish and North Seas. Thus was the North Sea Basin initiated.

The Permo-Triassic (270 - 180 m.y. BP)

The raising of the Hercynian mountain chains cut off moisture-bearing winds from the area of the British Isles and adjacent North Sea, and this region, hemmed in between the Caledonian and Hercynian mountains became an arid area with internal drainage. Close parallels exist with the Basin and Range Province of the present-day western United States. However, it should not be forgotten that at this time there was also no Atlantic

Ocean, and the British Isles area was situated at about 30°N latitude, i.e. in equivalent latitudes to those at present occupied by the Sahara desert.

During much of the Permian the North Sea Basin was occupied by a hypersaline sea, with a restricted marine fauna at times, and at others undergoing more extreme evaporation to the point of precipitating potassium salts.

The lower part of the Permian is, however, represented by the Rotliegendes Formation. In the south of the basin this is composed of dune sands, which now form the reservoir beds for North Sea gas, distilled from the deeply buried Coal Measures underneath. To the north these give way to siltstones with intercalated anhydrite, and eventually to a basin containing rock salt or halite, which terminates eastwards under Schleswig Holstein, and extends westward as a belt across the North Sea towards Yorkshire. From the lack of association of the halite deposits with other evaporite minerals, Brunstrom and Walmsley (1969, p.871) conclude that they were the product of inland drainage.

The succeeding Zechstein Formation represents the establishement of a hypersaline sea in the North Sea Basin (see Fig. 2). It is represented at outcrop in Northeastern England by the Magnesian Limestone, which is in part a barrier reef at the edge of the Zechstein Sea. Four cycles of evaporation are recognised in the Zechstein deposits, the evaporite minerals from which have long since been famous from their development at Stassfurt in Germany. The main developments of rock salt are in the Z_2 and Z_3 cycles (approximately 350 and 200m thick respectively; see Fig. 1). These evaporite deposits covered a wide area, the inflow of salt-bearing waters coming from a marine area to the south.

Arid conditions continued in the following Triassic, with extensive red bed deposition in the Midlands area of the British Isles and the North Sea Basin (see Fig. 3).

Fig. 2. Permian deposits of the North Sea Basin (after Kent 1967A, and Brunstrom and Walmsley 1969)

Key: Limits of Zechstein
Limits of Zechstein salt
Limits of area of salt plugs and masses
Salt plugs and masses (including diapirs)
1. Norwegian Salt basin 2. English Salt basin
3. German Salt basin.

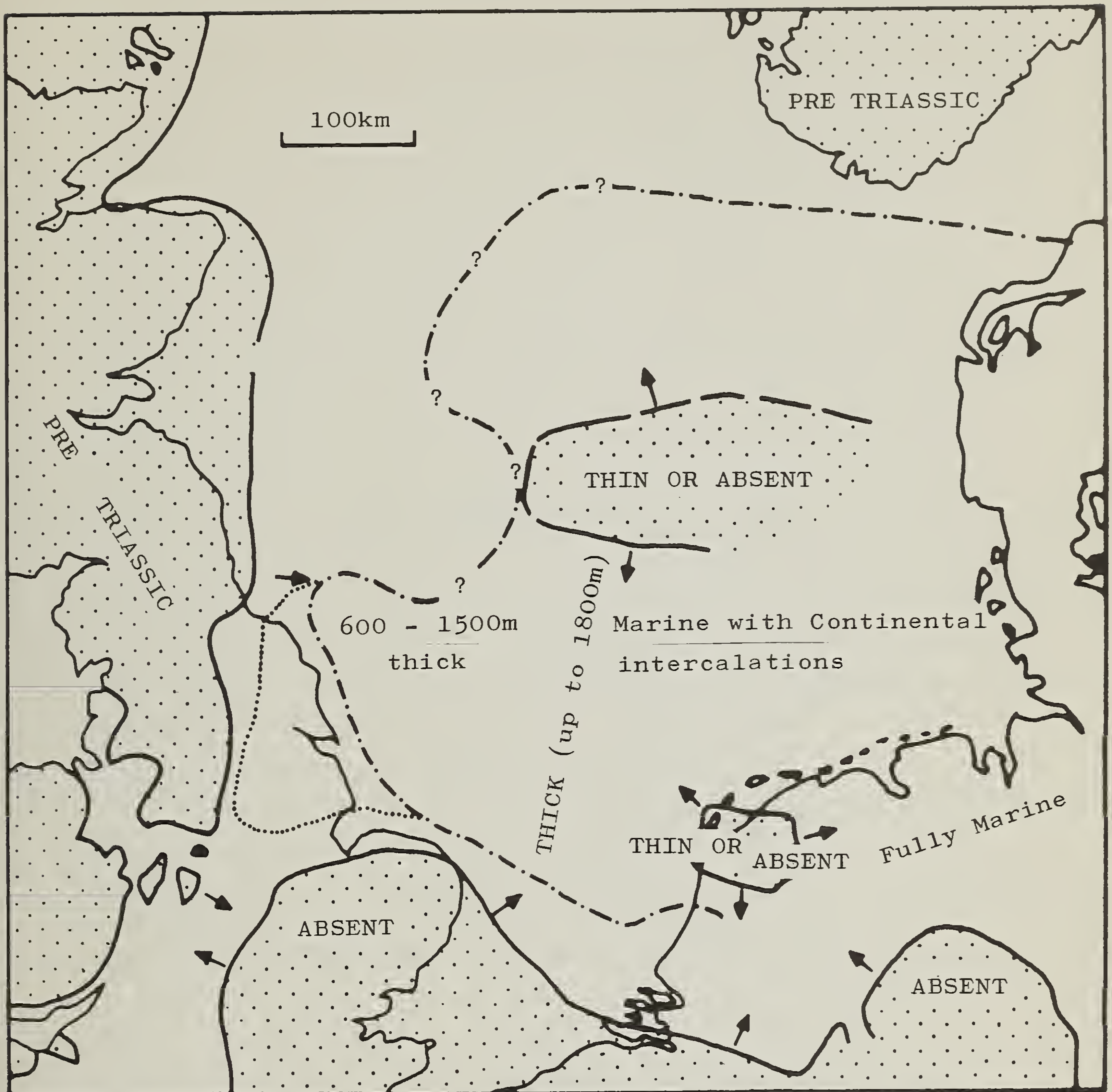


Fig. 3. Triassic deposits of the North Sea Basin (after Kent 1967A)

Key: Limits of Triassic deposits
Limits of Muschelkalk Sea
(minor marine tongue)

Differential movements and block-faulting, possibly associated with the earliest phases of opening of the Atlantic Ocean, were rather characteristic, and the accumulation of considerable thicknesses of sediment led to incipient halokinesis or salt tectonics affecting the underlying Zechstein salt beds (see Fig. 4).

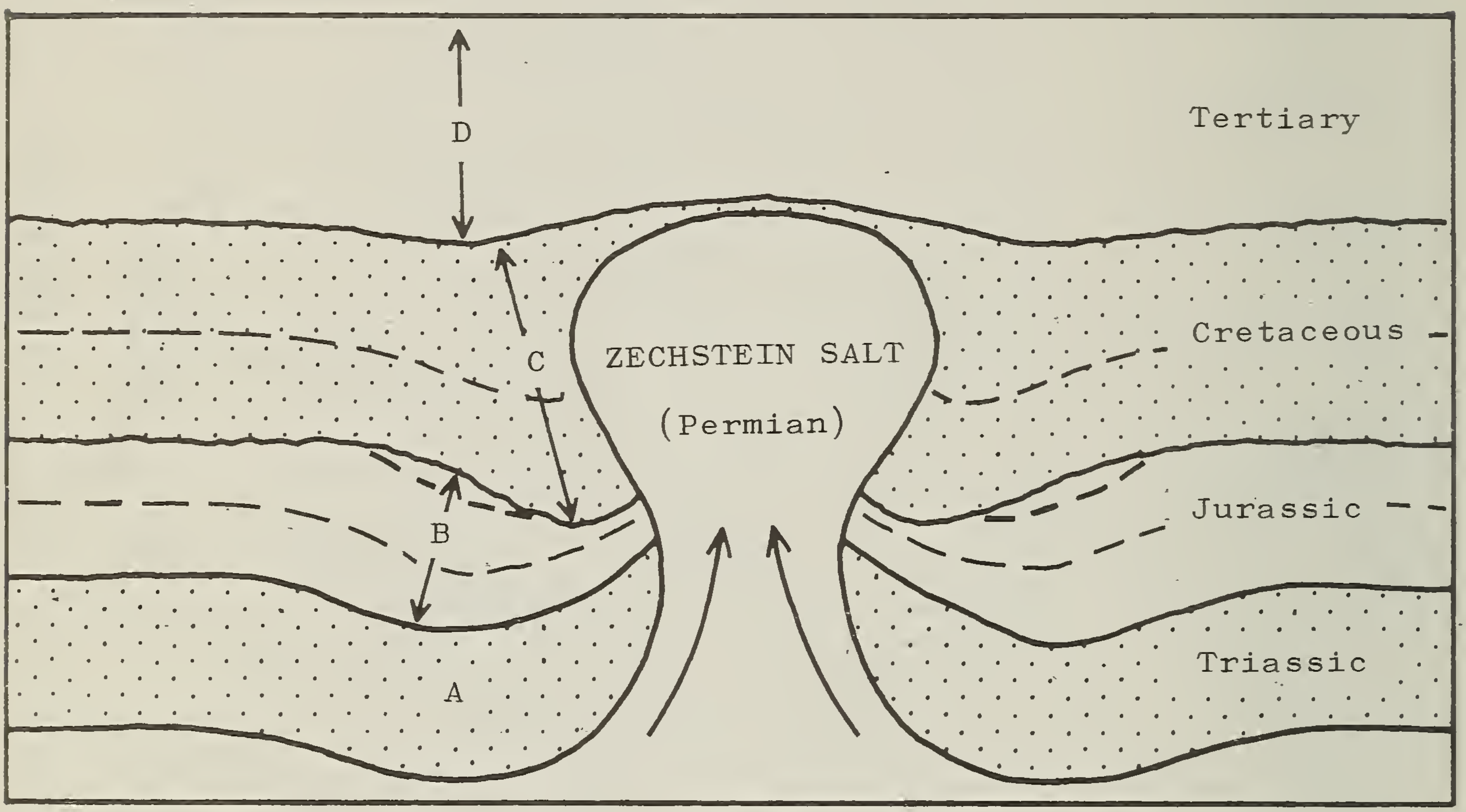


Fig. 4. Idealized section through a North Sea Basin salt plug and adjacent strata (after Brunstrom and Walmsley 1969)

A. Pre-movement stage (Triassic)
B. Pillow stage; primary peripheral sink develops (uppermost Triassic and Jurassic)
C. Diapir stage; secondary peripheral sink develops (Lower and Upper Cretaceous)
D. Post diapiric stage; third-order peripheral sink (Tertiary)

The Bunter division, which in the Midlands consists of pebble beds and dune sands, passes laterally under the North Sea onto marley beds containing fine sandstones and thin developments of rock salt and anhydrite. The middle division of the German sequence - the Muschelkalk, which represents the development of a hypersaline sea with an impoverished fauna, is found extensively under the North Sea and extends close to the present coast of the British Isles. There was a small ephemeral extension onto the arid plains of the east Midlands. The main development of the Muschelkalk consists of alternations of mudstones, dolomites, rock salt and gypsum. The Keuper division, succeeded by the lagoonal marine deposits of the Rhaetic, which heralded the return of the normal salinity Jurassic seas, is widespread. However, the thickness of sediment resting on the Zechstein salt was already approaching or even exceeding 1000m before the end of the Triassic, and both Keuper, and particularly Rhaetic, may be absent through erosion from above salt culminations (pillows or domes).

<u>Jurassic and Lower Cretaceous</u> (180 - 100 m.y. BP)

The movement of salt which commenced in late Triassic times continued actively in the Jurassic and Lower Cretaceous, and abnormal thickening of deposits occurred between the active salt plugs (see Fig. 4).

Generally speaking the Lower Jurassic, or Liassic, sequence is well-developed (Fig. 1), but even this has often been removed by pre-Upper Cretaceous erosion. The Middle and Upper Jurassic actually thins eastwards towards the North Sea from its fullest development in the Midlands, as does the Speeton Clay of the Lower Cretaceous succession, and Jurassic and Lower Cretaceous sediments are thin or absent over considerable tracts of the North Sea Basin (Fig. 5). Much of this absence is probably the result of pre-Upper Cretaceous erosion, and both halo-kinetic and tectonic movements are clearly factors contributing to it.

Thus it is clear that during the Jurassic and Lower Cretaceous the North Sea Basin did not form a major site of marine sedimentation, although continuity of marine waters across the area is implied - for instance by the similar faunas of the Yorkshire and Lincolnshire and the Netherlands Lower Cretaceous.

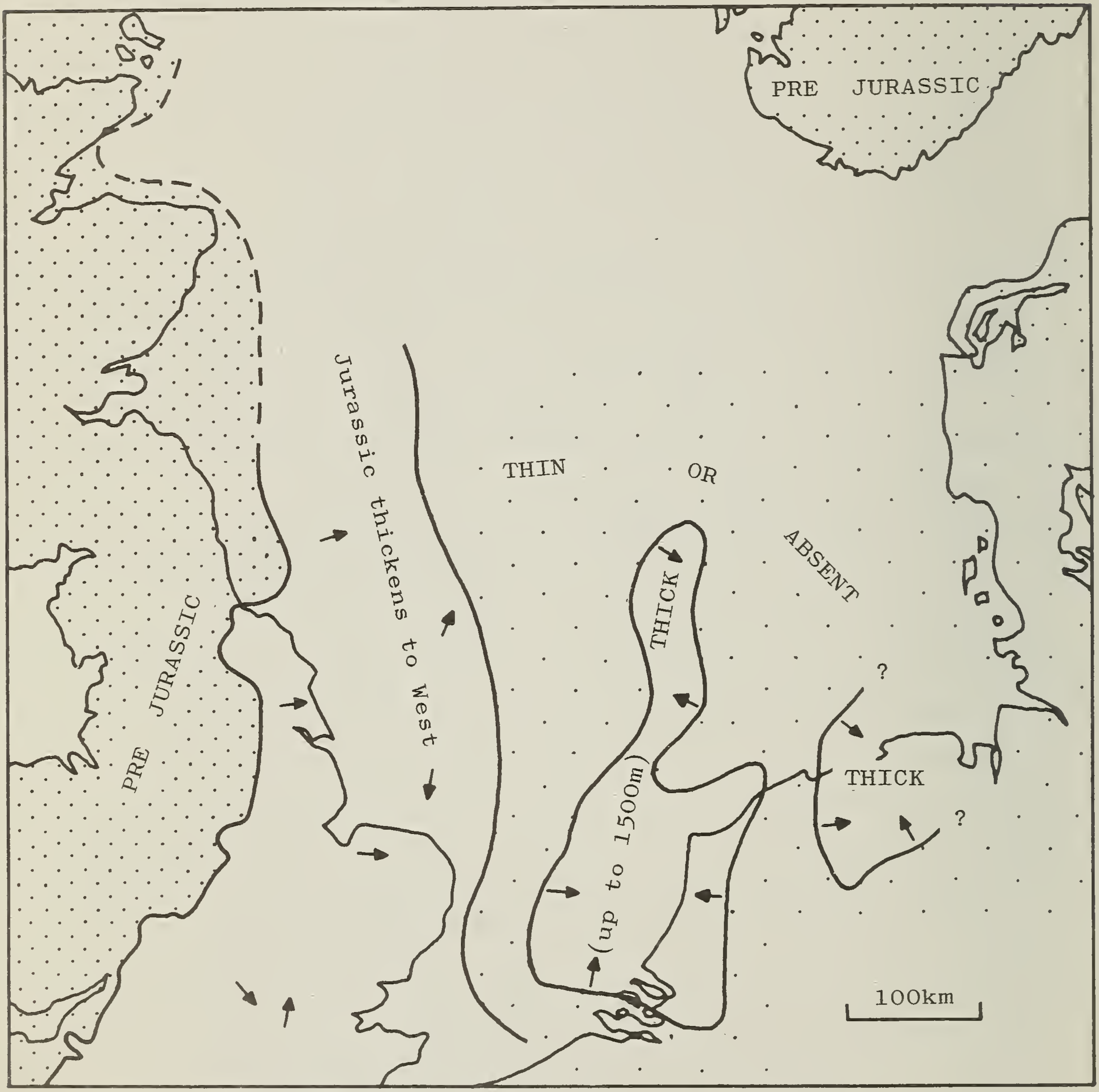


Fig. 5. Jurassic and Lower Cretaceous deposits of the North Sea Basin (after Kent 1967A)

Upper Cretaceous (100 - 65 m.y. BP)

Following the extensive halokinetic and other tectonic events of the Jurassic and Lower Cretaceous, with their accompanying erosion and localised deposition, the Upper Cretaceous was a period of extensive transgression. The sea spread broadly over both the North Sea Basin and surrounding areas (see Fig. 6). Apart from an initial period during the Albian, when erosion of exposed Triassic rocks in the North Sea Basin is thought to have contributed to the red colour of the Red Rock, the deposits were typically the same pure white chalk which characterises the Chalk formation on land. The presence of a basal Red Rock member, similar to that developed in Norfolk, Lincolnshire and Yorkshire, is typical, and extends eastwards as far as the Netherlands.

Thicknesses of up to 1,500m of Chalk are found in places, although it is thin or absent through erosion under the northern Netherlands, in a belt which extends half-way across the North Sea towards the Norfolk coast. It is also absent along an anticlinal zone extending parallel to the coast of Yorkshire and North Lincolnshire, within which Jurassic rocks outcrop on the sea floor. Salt movement continued during Upper Cretaceous times and locally Upper Cretaceous is absent through salt dome piercement of the Chalk formation.

Generally speaking, during this period the North Sea Basin formed only part of a much more extensive epicontinental sea, which flooded large areas of the British Isles and N.W. Europe. The Basin itself is only distinguished by the accumulation, in parts at least, of rather greater thicknesses of sediment than characterise the surrounding areas.

The North Sea

At the end of Upper Cretaceous times there was a widespread regression of the sea, associated, or at least

Fig. 6. Upper Cretaceous deposits of the North Sea Basin (after Kent 1967A)

concomitant with tectonic movements, that may themselves be related to the opening of the Iceland branch of the North Atlantic Ocean. At this time, or shortly following it, volcanic activity is noted at the eastern edges of the North Sea Basin (although nothing like as extensive as the contemporaneous volcanism of the Scottish Islands), and the present outlines of the Basin were largely defined. The Basin thus defined was occupied continuously by marine waters throughout the Tertiary until the present-day, and accumulated considerable thicknesses of sediments (see Fig. 7). From this time onwards the marine waters occupying the Basin can appropriately be referred to as the North Sea, and their history will form the subject of the sequel to this account, in the next issue of the Bulletin.

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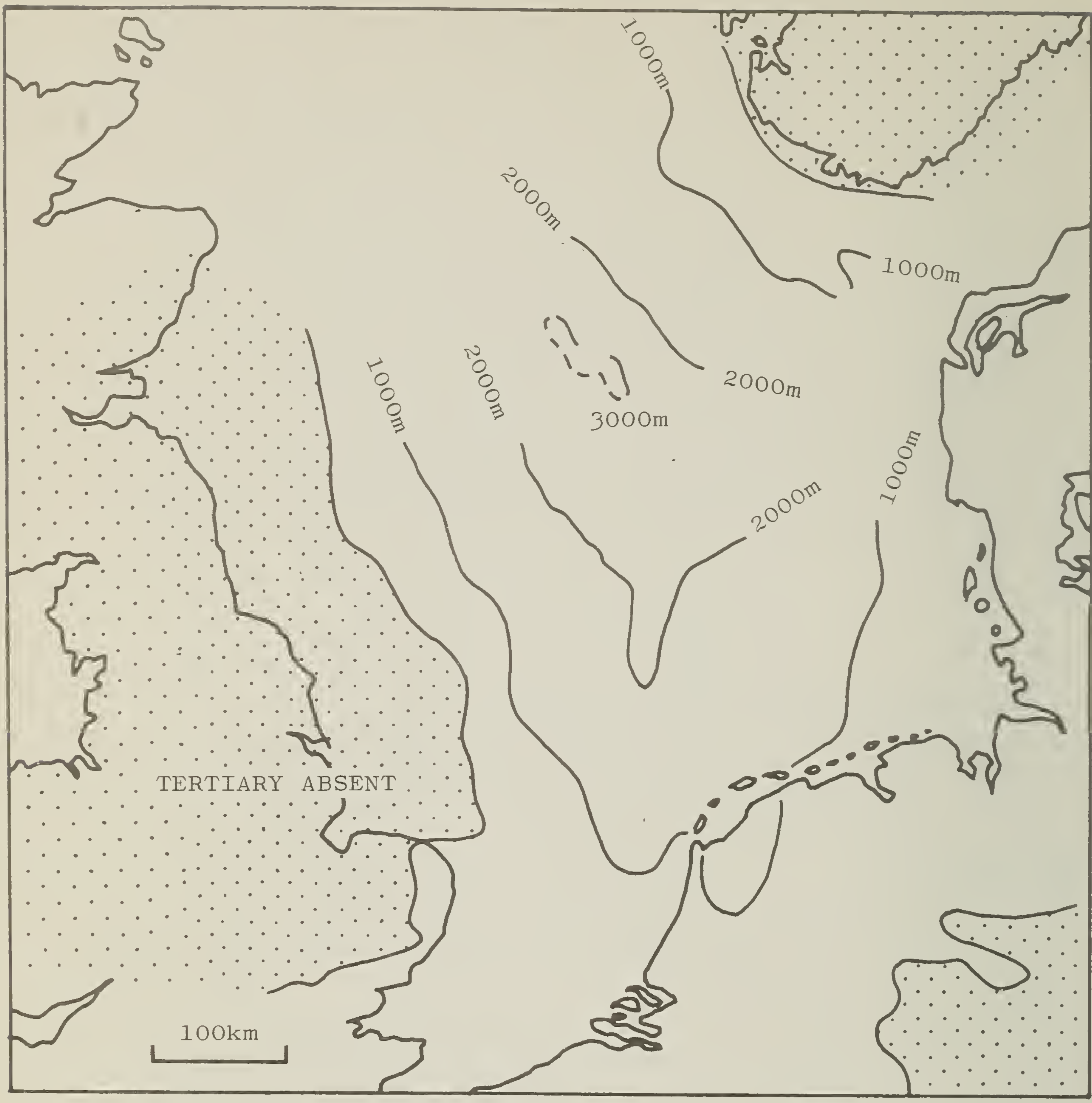

Fig. 7. Thickness of Tertiary deposits in the North Sea Basin (after Kent 1967A)

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ASPECTS OF GEOLOGY IN EDUCATION

H. EVANS*

All subjects within the curriculum have a limited vocational factor relative to the supply and demand of society. Geologists have been aware of such a situation for many years, and it is one which has now affected other natural sciences. It is a personal opinion that this has resulted in conservative elements within geology neither actively encouraging nor discouraging the teaching of the subject in schools. This is, in effect, a restrictive practice based on vocational considerations. The result has been to limit the degree of educational research into geology as a discipline of value within the school curriculum. From such a weak position it is difficult to justify its existence in competition with traditional subjects, while further limitations are imposed by economies of scale within, for instance, a grammar school. These are probably too small to consider real expansion of both curriculum and specialist staff. Therefore the excess of graduate geologists, who wish to teach, is often unable to find desirable employment in schools.

A. E. Trueman (1947) states, "Teachers must not think too exclusively of those who are to be professional geologists". In context this statement applied to school teachers, but this in no way invalidates its application to those in higher education. The expansion of the universities during the 1955 - 65 period enabled such attitudes to be inculcated, particularly with non-vocational Foundation and subsidiary courses. The newer universities were able to break with tradition and pave the way for wider curricula based on liberal thinking. Similarly, the number of courses now being offered by

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Extra Mural Studies and the Workers' Educational Association is some indication of the growing interest in recreational geology and allied subjects. The Foundation Courses of the Open University are a further indication of this trend.

Certainly, during the post-1945 period, geology in schools was predominantly restricted to industrial areas where its vocational considerations were fully realised. Since then there has been a steady growth in the number of General Certificate Examination entries and inroads have been made in the C.S.E. Mode 3 examination. To complement this, several colleges of Education now include geology for the Bachelor of Education degree. If growth is to continue in schools then this is most likely to be met by the larger units - comprehensives, large grammar and technical schools, where economies of scale are greater. It is only within such a unit that the recommendations of the Dainton Report (1968), with its emphasis on a broad span of sixth-form studies in science and technology, can be fully realised.

The potential for geology in a technical college is significant because of its utilitarian value in terms of arts, science and technology. Where courses are academically oriented, that is to O and A levels, it provides opportunities for science-based students with vocational aspirations in geology, or for arts students who intend reading geology at a subsidiary level to geography at university. Further opportunities are now provided by the innovation of university earth science courses with their wide appeal of option courses. In this respect it is interesting to note that K. Clayton (1970) considers earth sciences as offering a conversion towards science for the sixth-form arts student, an opinion which appears to concur with Dainton's suggested postponement of irreversible decisions for or against science as late as possible. In my experience there has been little to

choose between science or arts based students in geology at A level, though one naturally accepts the relevance of a science based course for specialised work. One must not underestimate the growing importance of Environmental Studies in the Colleges of Education, since a variety of subject combinations, including geology, can provide a sound base for teaching, particularly where team teaching is incorporated within a school.

Courses within my own college have been organised for teachers in which both theory and subject techniques have been an integral part of the course. This has directly influenced the introduction of geology in a local school. As a service department, it has been of particular use with building courses, by providing information and materials on basic rock-types. In this connection a course has been run for local building firms.

<u>Geology Teaching</u>

Most of the students elect for geology A level with little or no previous experience of the subject. Therefore it is essential that material must be carefully selected for its wide appeal, since future student attitudes will possibly depend on the introduction to the subject. The following points of observation are critical in developing confidence, and a class rapport between teacher and taught. I might add that they can be equally applied to any other subject.

(i) The majority will have a lack of confidence in commencing a new subject.

(ii) They will tend to measure progress against a text-book standard, and regard their own intellect with a sense of inferiority.

(iii) Teaching appears to promote a state of perfection in which errors must be apprehended, often to the detriment of student or pupil confidence. This form of punishment within a learning situation

can stifle all subsequent discussion; even of the simplest problems.

It is possible to organise the subject matter in many ways, which could be discussed at length. The most usual practice is to teach the individual branches of the subject concurrently, a method which tends to follow closely the outline of an examination curriculum. The advantages of this system can be fully exploited if there is a continuous integration of material; otherwise it is some time before a student realises the implications of geology.

As an alternative I suggest three group studies or natural divisions in which maximum continuity and integration is feasible, and provides a large measure of success and satisfaction for the student.

The first grouping, (Fig. 1), is a natural division based on igneous petrology, but with an integration of earth-structure, mineralogy and ore deposits. The

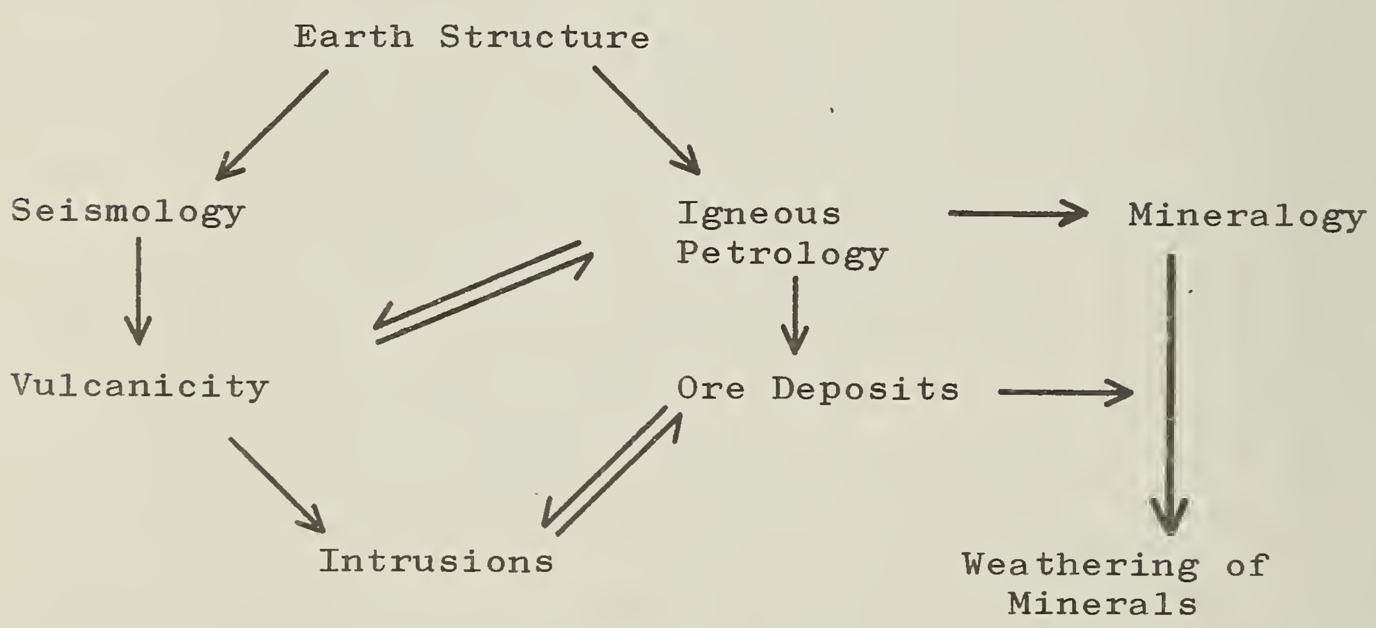

Fig. 1. Group Study showing the integration of allied topics based on igneous petrology.

introduction of a stimulating topic like vulcanicity in the early part of the course has advantages. The students already have some previous knowledge which does contribute to a higher degree of oral response, and more effective teaching as a result. This also has the effect of instilling confidence. It is essential at this stage to introduce rock and mineral specimens, even with the first lessons on simple magmatic differentiation and textural considerations. One cannot expect granites to be identified without some knowledge of the mineral constituents in both theory and hand-specimen. The intention is to avoid classifications and mineral content being learned on a rote method, so that application, rather than knowledge for its own sake is encouraged. The mineralogy follows a sequence in which the rock forming minerals are followed by those of economic geology. The introduction of weathering at this point is relative to the mineralogy, and introduces the second grouping.

This grouping, (Fig. 2), has a predominantly sedimentary theme initiated from a study of erosive forces, and correlated with both palaeontology and stratigraphy. The environmental concept can be a unit in which a euxinic, deltaic or desert environment, for example, can be directly selected from a geological period, but it is moderately difficult to elucidate stratigraphical principles from such units. Therefore examples are chosen from Lower Palaeozoic sedimentation, which correlate rock-types and structures with a study of graptolites and trilobites. Within this context the discussion of time, zones and facies change form a natural linkage factor. Further studies can include limestone diagenesis - Wenlock or Lower Carboniferous bioherms - corals, crinoids; or sandstones and structures - Carboniferous deltas - rhythmic sedimentation - lamellibranchs. The brachiopods, lamellibranchs and gastropods are difficult to correlate because of their

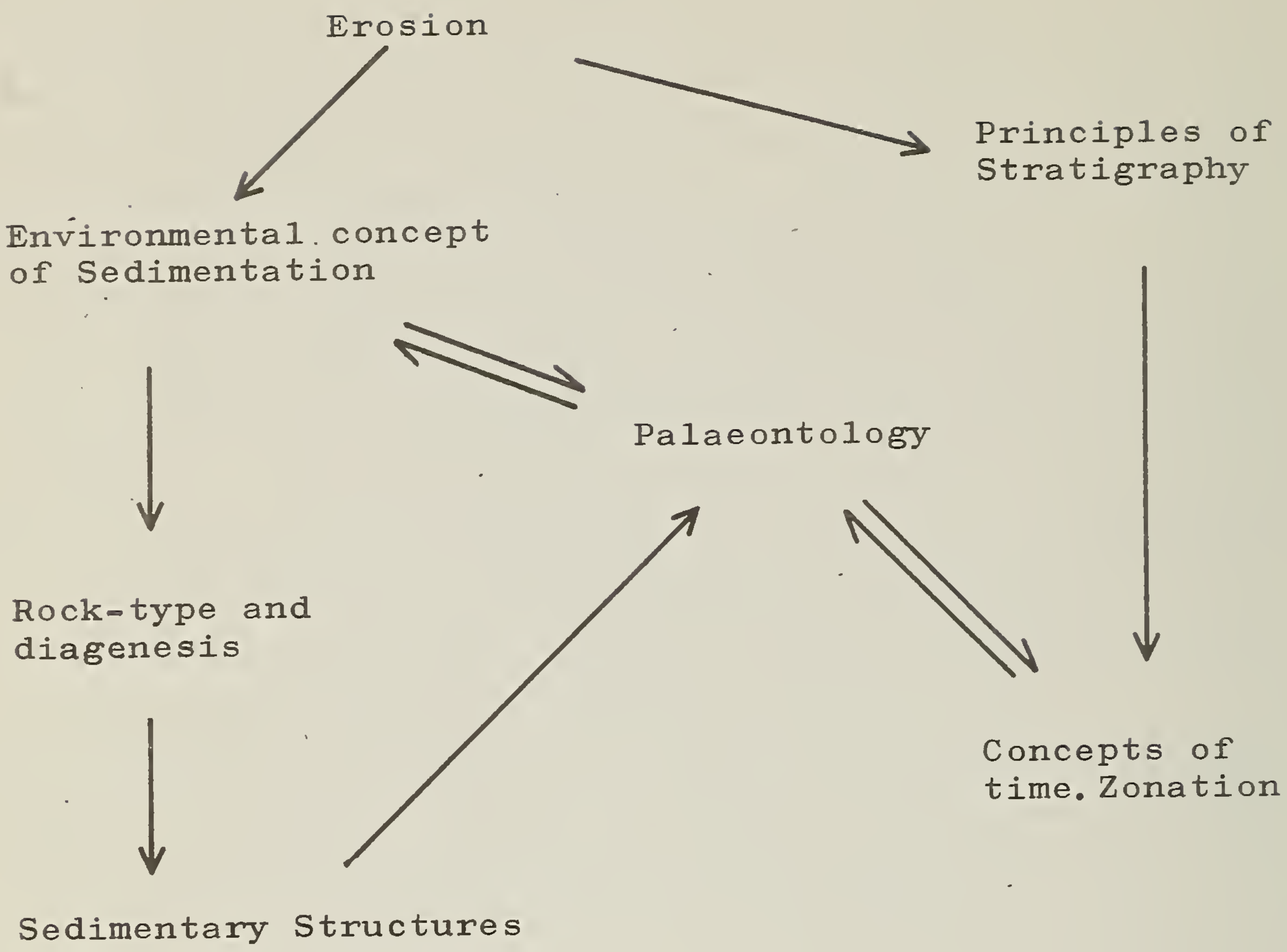

Fig. 2. Group Study illustrating the relationship between three major branches of geology and their organisation for teaching.

adaptation to a broad range of environmental conditions throughout geological time, and there is a danger of fragmented teaching. In this case they are regarded as units and this does have the effect of extending the course outside its grouping.

A third grouping consists of metamorphism linked with geosynclinal concepts, mountain building and continental drift, a course which, in view of the time factor, runs concurrently with stratigraphy. The foundation for the latter has already been laid and enables the student to view the subject with some measure

of proportion. This is not always achieved, but can avoid lists of beds rather than an intelligent and interesting interpretation of events.

The teaching of structural geology and map interpretation is coordinated with the main groups of work. Initially, the maps are a source of reference, but they broaden into the wider aspects with the introduction of stratigraphical principles in the second group of study (Fig. 2). Of course one is actually teaching these principles from the first field trip. Field work follows a similar pattern so that a course on the Lower Palaeozoics of North Wales or Shropshire is conducted at the end of the first year, and contrasted with the Mesozoic of the East Riding or Dorset during the second year. Local day excursions also form a significant part of the course.

In terms of time, based on six-hourly periods per week, the first group study is likely to take 18 to 20 weeks, the second group study some 13 to 15 weeks but with an extension of time for palaeontological groups. The stratigraphy and the third group study run parallel, the former taking a substantial part of a second year course.

It is of course possible to rearrange these groupings, and commence with the principles of geology. I prefer this method for reasons stated in the introduction to this section, and consider that the group system has the following advantages.

(a) There are no barriers across the timetable; one can organise work without fear of cutting across some other branch of geology.

(b) Students can concentrate on a main theme rather than a disjointed approach, this provides continuity.

(c) The integration of work provides for a much more fluent approach to both written and oral work, and there is continuous recapitulation.

(d) The use of specific examples becomes multipurpose rather than a limiting factor.

Resources

The choice of A-level text-books is limited and those available leave a lot to be desired in terms of content, and particularly from the point of view of material written in an interesting way. There is little attempt to demonstrate the inter-relationships between various branches of the subject, which can result in a form of 'pigeon-hole' thinking. Students require little encouragement in this respect. There are very few books written on stratigraphy, while crystallography is often regarded as a glossary of axes and crystal forms. In view of this situation, most material has to be carefully selected and supplemented by reference to duplicated notes, scientific journals and selected reading. Fortunately I have access to a first class library at my own college. Visual aids normally consist of slides, overhead projectors, photographs and to a lesser extent films.

Perhaps the most useful resource is the collection of rocks and fossils which provide a focal point for the majority of lessons. The mass of material carried can reach alarming proportions, particularly with some common igneous rocks and limestones. An attempt is made to provide as many class collections as possible so that classroom organisation is reduced to a minimum, while at the same time the interest of the individual can be maintained. A further feature is the portability of such collections in using a variety of rooms. The cost of supplying and maintaining collections is relatively small since much material is collected on excursions, and some is donated by interested staff and friends of the college. Though thin-section studies are no longer a part of the London syllabus, microscopes are used for examining textures of igneous and metamorphic rocks.

The regional position of King's Lynn is such that

it is not reasonably endowed with a variety of suitable outcrops. Full use is made of local geology, but day excursions have to be made to the Jurassic of the Stamford area or the Pre-Cambrian of Charnwood Forest. Reference has already been made to other excursions. An important aspect of this work is to encourage an appreciation of the countryside in its widest context, and to have consideration for an outcrop which may have intrinsic value to someone else.

Any future development of geology, either as a single discipline, or under the guise of environmental studies, will only do so through an expansion of the curriculum. This will initially depend on increased expenditure on education, and possibly where schools are re-grouped into larger units. Compared with traditional subjects there is a general lack of comprehension of both its content and value; a state which can be overcome through educational research.

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THE ZONES OF THE GIPPING VALLEY CHALK, SUFFOLK

R. A. D. MARKHAM*

Jukes-Browne (1903) referred the Gipping Valley Chalk to the Zone of *Actinocamax quadratus*, and Boswell (1912) recorded the overlying *Belemnitella mucronata* zone from Bramford. The *quadratus* zone of the Gipping Valley was called the zone of granulated *Actinocamax* by Brydone (1932), as the old zone of *A. quadratus* in the south of England had by then been divided into a lower zone of *Offaster pilula* and an upper zone of *Actinocamax quadratus* (restricted). Gaster (1941) referred the chalk below the *mucronata* zone in the Gipping Valley to the zone of *O.pilula*, concluding that the *A. quadratus* zone (restricted) was missing.

In the nineteen-fifties, plates of the zonal crinoid *Marsupites* were found by C. Allen and R. Markham in the lowest chalk exposed in 'Masons' pit, Great Blakenham (TM 112499).

In the mid nineteen-sixties, chalk with *Gonioteuthis (=Actinocamax) quadrata* was found above the chalk with *Belemnitella* at Church Lane, Claydon (TM 136498). Peake and Hancock (1961) suggest that *Belemnitella* from their *Gonioteuthis* zone (=Brydone's zone of granulated *Actinocamax*) in Norfolk may be *B. praecursor*; several specimens of *Belemnitella* (of the type formerly thought to be *B. mucronata*) from Claydon and Bramford (TM 129482) were kindly identified for the writer by M. R. Leeder as *B. praecursor*. It now appears that the zone of *Belemnitella mucronata* does not occur in the Gipping Valley, which solves several problems ——

Gonioteuthis (=Actinocamax) granulata does not occur zonally higher (i.e. immediately under *mucronata* chalk) in Suffolk than elsewhere (Boswell 1927), and there is no

* Ipswich Museum, High Street, IPSWICH.

need for an unconformity between mucronata and pilula zones (Gaster 1941). The thickness of the Gonioteuthis zone (s.l.) is probably similar to other parts of the country.

The Gipping Valley Chalk shows Gonioteuthis zone on Marsupites zone; the Gonioteuthis zone may be subdivided into an upper, quadrata zone and a lower, pilula zone. Gonioteuthis of the granulata type is characteristic of the pilula division.

Until more detailed studies are made, the Gipping Valley Chalk may for practical work be divided as follows -

5 - division of Gonioteuthis quadrata
4 - " " Belemnitella
3 - " " Gonioteuthis and Echinocorys
2 - " " Gonioteuthis (Inoceramus and Ostrea also common)
1 - " " Gonioteuthis and Marsupites

The alveoli of Gonioteuthis in division 5 are generally deep and quadrate; in divisions 1, 2 and 3 the anterior ends of the guards are usually imperfect, and the few alveoli seen are not quadrate nor quite so deep.

Bands of flint nodules are common in divisions 4 and 5. Echinocorys is common in divisions 3, 4 and 5, but less so below. Little work has so far been done on thicknesses, but division 2 is the thickest.

The echinoid Micraster may here be recorded from Bramford (Brydone collection, in Ipswich Museum) and Claydon (found by R. Forsdike).

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A FOREST BED HORSE JAW FROM PASTON, NORFOLK

R. A. D. MARKHAM*

In the collection of Dr. W. H. Miller of Mundesley is a fine mandible of horse, found on the beach at Paston; the state of preservation and adhering matrix leave little doubt as to derivation from nearby Forest Bed deposit.

Most of the left side and portion of the right side are preserved. On the left side the ascending ramus is missing; all six cheek-teeth are present, also the canine, but of the incisors only I_1 is perfect, 2 and 3 being broken off below jaw level. On the right side, all the incisors are broken below jaw level; the canine and one cheek tooth (second premolar) are present, the jaw being broken off behind this.

Left side:

Diastema length, I_3 - P_2 (measured between base of teeth; difficult as I_3 broken)	c. 113 mm.
Length of cheek-tooth row, P_2 - M_3 (grinding surface) (measured from end of parastylid of P_2 to end of hypoconulid of M_3)	207 mm.
Length of premolar series (grinding surface) (measured from end of parastylid of P_2 to outer edge of hypoconulid of P_4)	108 mm.
Height of ramus at P_4 M_1	106 mm.
Height of ramus at centre of M_3	c. 132 mm.
Height of ramus at rear of M_3	c. 147 mm.

* Ipswich Museum, High Street, IPSWICH.

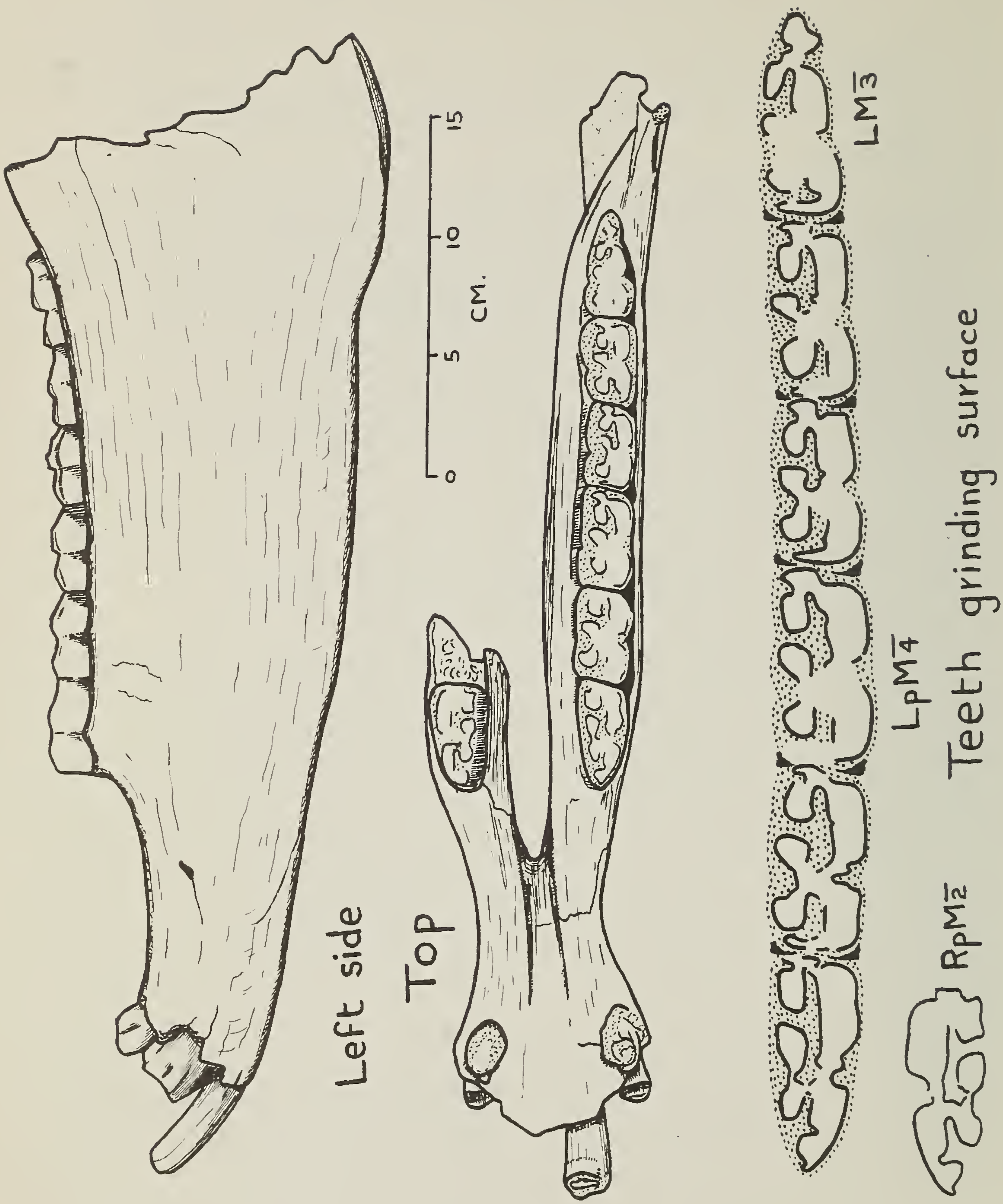

Fig. 1. Horse jaw from Forest Bed, Paston

Right side:

Diastema length, $I_3 - P_2$ c. 115 mm.

(measured between base of teeth, at edge of socket; difficult, as I_3 broken).

Adhering matrix obscures the metastylid - mesostylid valley in LM_3, LM_2 and LpM_4, but in the rest of the cheek teeth it is close to the "U" shape of the caballine horses and is unlike the "V" of the so-called zebrine group. The complete incisor shows the cup or 'mark' on the wearing surface.

I wish to thank Dr. Miller for permission to examine and note this specimen.

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RAILWAYS AND GEOLOGY - A WALK FROM NORTH WALSHAM TO PASTON AND KNAPTON

(Field Meeting, June 3, 1971)

R. S. JOBY

The branch line from North Walsham to Mundesley traverses superficial glacial deposits of varying types and also crosses the valley of the River Ant. This provided an opportunity to examine exposures in cuttings, which revealed rapid transitions from sand to clays, and back again. Vegetation variations on the differing deposits were also noted.

The remains of the ballast on the roadbed appear to be Kelling Heath gravels, quarried by the M. & G. N. Railway in its own pit. This is mixed with furnace slag. More recent non-local material noted was a finer gravel used in connection with the use of the roadbed as a gas pipeline route, and this appeared to be markfieldite.

The alluvium of the Ant valley was easily picked out by the change in vegetation, which coincided almost exactly with the boundary on the 1" Geological map. Other geological boundaries shown on the same map were not so readily discernible, and there appeared to be a zone of change in the deposits rather than a distinct line.

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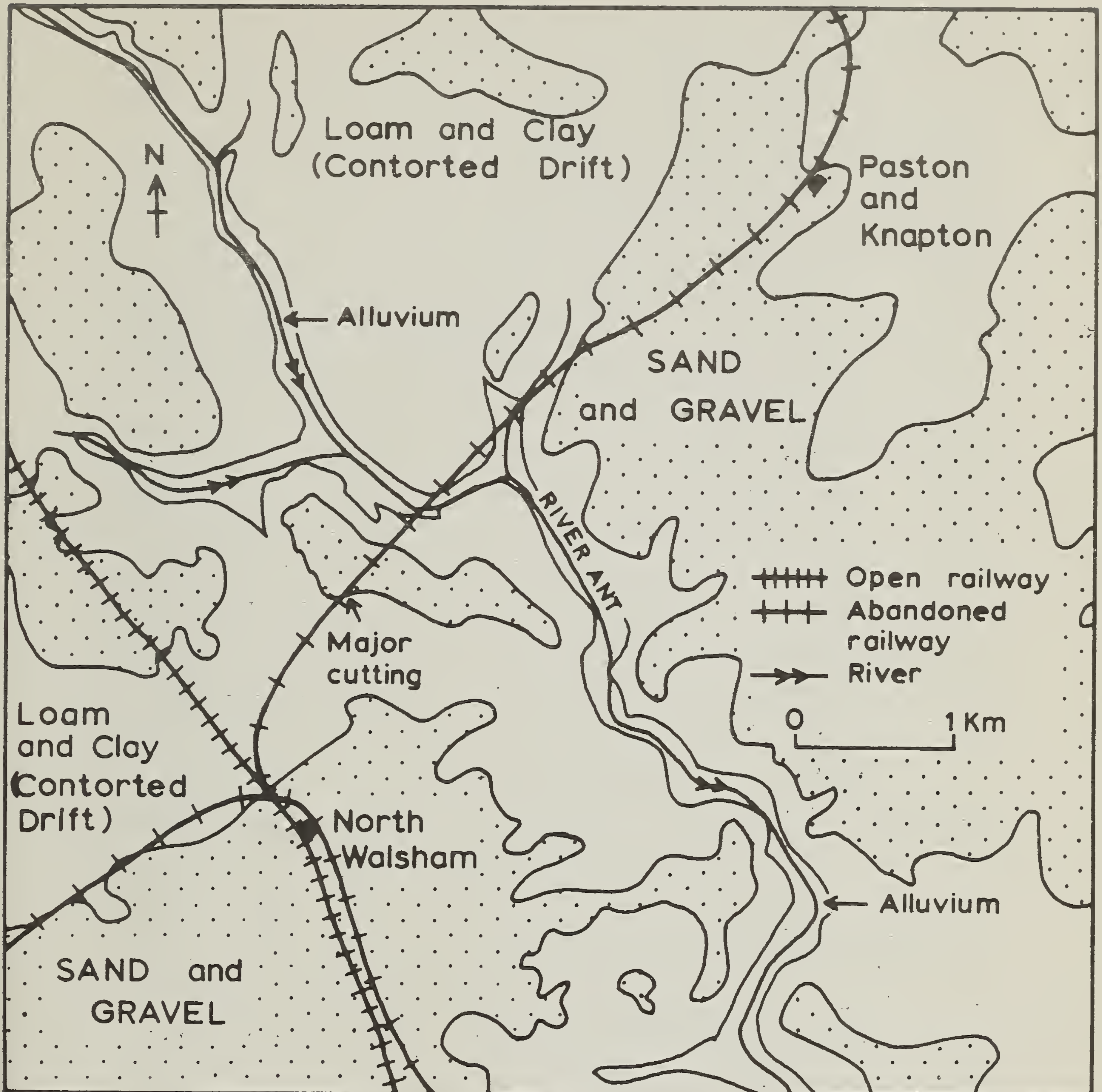

Fig. 1. Superficial Geology of North Walsham area

REPORT ON FIELD MEETINGS TO WANGFORD, AND EAST SUFFOLK

P. G. CAMBRIDGE *

Two field meetings on July 8th and August 1st 1971 included visits to representative sections of most of the East Anglian Crags, with the exception of the Waltonian and Weybournian stages which were not seen.

Hill Farm, Wangford (TM 462777)

In 1969 a section was re-excavated in an old pit showing shelly Norwich Crag of littoral type, passing up into bedded gravels. Recent workings in the gravel pit to the northern side of the road have reached the base of these gravels and penetrated shelly sands. Unfortunately, owing to the method of working the gravels, the junction between the two types of deposit could not be clearly seen, but there seemed no reason to suspect that it differs from the top of the section in the old pit. Five members attended the meeting and representative collections of the abundant molluscan fossils were made. The abundance of Donax vittatus (Da Costa) and the large size and excellent preservation of the examples of Littorina littorea L. and Nucella lapillus (L) attracted attention. Several fragments of mammalian bones, possibly elephant, were found, while the author found a single valve of the freshwater bivalve Corbicula fluminalis (Müller) in a sample. Finally an interesting bed of Fragaria vesca was discovered on the the side of the valley and the meeting was extended to enable members to collect - and eat - these delicious wild strawberries.

East Suffolk

Twelve members and friends assembled at Orford Castle and climbed the keep. Visibility was very good and parts of the coast from Walton-on-the-Naze to Aldeburgh were seen. The general distribution of the Crag beds,

* 258 Bluebell Road, NORWICH.

the drowned valleys and the structure of Orford Ness were discussed.

The first exposure was at Crag Farm, Sudbourne (TM 429523) where a good section was seen in the bullockyard. It was a common practice to cut bullock-yards in the Crag and to use the material excavated for farm roads, rough walling or spreading on the land. The Coralline Crag Rock Bed is partially decalcified so that aragonite fossils were seen only as moulds in the rock, (Laevicardium, Glycymeris, etc) while calcitic fossils remain (Pycnodonte, Anomia, Lima, polyzoans, crustacea). At this pit the current bedding was well seen and, along what appeared to be joint planes, some traces of Red Crag were noted, showing that the Red Crag formerly enveloped the Coralline Crag deposits.

After refreshments at the Oyster Inn, Butley, the Church Pit at Chillesford (TM 383523) and the Neutral Farm Pit, Butley (TM 371511) were visited. The composite section in the two pits shows Butleyan Red Crag overlain by the Scrobicularia Crag and the Chillesford Crag. The Red Crag of this stage contains many large bivalves as well as small well-preserved molluscs (Calyptraea, Ringiculella, Odostomia, Mangelia, Nassarius, Hiatella). An example of Spirotropis modiola (Jan), was found in the Neutral Farm Pit, almost certainly derived from the Pliocene and demonstrating the reworking that continued throughout the Red Crag.

Examples of the typical Scrobicularia plana (Da Costa), an estuarine form, were collected in the Church Pit and it could be seen how conditions were altering. Coarse shelly shands, strongly current-bedded, which are typical of the Red Crag, give way to silty layers of increasing thickness in which examples of Spisula and Macoma were seen with the valves still joined. In the Chillesford Crag in the upper part of the Church Pit members saw Mya truncata L. in the position of growth, emphasising

the undisturbed aspect of the beds.

The last pit visited was a sand and gravel working on Waldringfield Heath (TM 263448) in glacial outwash. There is a distinct change in lithology between the pale waterlaid sands of the outwash, and the darker marine sands of the Crag. Although decalcified, these upper layers show signs of biogenic activity in the form of numerous burrows, partially solidified by iron compounds (?Balanaglossus). Similar burrows are seen in the Scrobicularia Crag, at Chillesford, and elsewhere. A large pumping trench in the bottom of the pit penetrates the shelly Crag of the Newbournian stage. Acropagia, Mya, Arctica, Neptunes, Nucella and other molluscs were collected. Near the bottom of this trench were numerous phosphatic nodules, worn fish teeth and fragments of Coralline Crag and London Clay, which may have come from the basal nodule bed of the Red Crag.

Our thanks are due to the owners and occupiers of the land who freely gave permission to examine the various sections and thus made the meetings possible.

Received August 1971

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Copies of this Bulletin may be obtained 60p (post free) from the Society at the Castle Museum, NORWICH, NOR 65B; it is issued free to members.

Also available at 75p (post free) is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 21

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BULLETIN of the GEOLOGICAL SOCIETY OF NORFOLK

No. 21 April 1972
Editor: R. S. Joby
116 Gowing Road, NORWICH, NOR 40M

EDITORIAL

In this issue we publish the second Presidential Address continuing and concluding the story of the North Sea, and another article on Geology in education. Further articles on the latter subject are being prepared as part of a series. We have some new ideas on stratigraphical relationships in the early Pleistocene, an account of a new borehole and a detailed and informative account of coastal erosion based on one of the Society's field meetings. Articles on molluscs and pollen from Aldeby, and mammals of the last interglacial in Norfolk will appear in the next issue.

Bulletin No.22 will be issued in September 1972. Contributions should be sent to me as soon as possible, and no later than July 31, 1972.

Will contributors please note that manuscripts are acceptable in legible handwriting, although typewritten copy is preferred. In either case it would be a great help if details of capitalisation, underlining, punctuation, etc., in headings and references (particularly), could conform strictly to those used in the Bulletin. Illustrations intended for reproduction without re-drawing should be executed in fine, dense, black ink line. Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations, should, before reproduction, fit into an area of 225mm by 175mm; full use should be made of the second (horizontal) dimension, which corresponds to the width of print on the page, but the first (vertical) dimension is an upper limit only.

R.S.J.

THE HISTORY OF THE NORTH SEA
(a summary of the Presidential Address for 1970, delivered January 14, 1971)

B. M. FUNNELL*

The Tertiary Setting

At the end of the Cretaceous times the North Sea Basin was defined in very much its present form. Since then it has accumulated up to 3000 m of sediment in its northern part, and up to 1000 m in the south (Funnell 1971).

At first the Palaeocene sea was relatively cool, as witnessed by the presence of such bivalve molluscan genera as Arctica and Macoma in the Thanet Sands of the London Basin. During the Eocene, however, conditions became sub-tropical, at least in the S.W. part of the North Sea. At that time the Wealden Island was not present, and the London and Hampshire Basins jointly accumulated muddy sediments on the N.W. shore of an otherwise clear and broad straits opening directly into the Atlantic. These straits were bordered on their S.E. side by the lagoons and mainly clear seas of the Paris Basin. Along the shores of the straits, and extending into the S.W. part of the North Sea, lived sub-tropical marine forms such as large bivalve and gastropod molluscs (including volutes and cowries), and larger Foraminifera; onshore palm trees flourished, whose remains are now regularly washed from the London Clay cliffs of the Isle of Sheppey. Further into the North Sea, in the equivalent deposits of Denmark, the sub-tropical influences are less evident.

Earth movements along the line of the English Channel led to the raising of the Weald anticlinorium and other structures in southern and south-eastern England from middle Oligocene times onwards, and deposition in the London, Hampshire and Paris Basins ceased. Restricted interchange of Atlantic with North Sea waters was probably the inevitable consequence of closure of the Lower Tertiary

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straits, and this is reflected in the cooler water molluscan assemblages found in the North Sea during the Miocene. Nevertheless these were still of warm temperate aspect, reaching an indication of maximum warmth in the Middle Miocene. At that time sea-level probably topped the raised Chalk cuestas to open broadly into the S.W. North Sea from the Atlantic once more. Conditions continued to be rather similar up to and including the Pliocene, although by this time the over-riding effects of world-wide climatic deterioration were already beginning to become apparent, and were soon to affect drastically both faunas and sea-level in the North Sea.

Plio-Pleistocene Events

Pliocene deposits in eastern England, Belgium and the Netherlands, and under the central southern North Sea, include a facies containing abundant bryozoans, well-known in parts of the Coralline Crag. Such bryozoans need a solid substrate on which to grow, and the presence of their remains in cross-bedded deposits such as the Coralline Crag implies post-mortal transport, and incorporation into hydraulic dunes or sand waves on the sea floor away from their point of origin. At the present day byrozoans grow, and their remains are produced prolifically, on the sea floor due west of Brest in the Western Approaches to the English Channel. A broad belt containing their abundant remains, albeit progressively diluted with molluscan shells, extends N.E. into the English Channel, between and beyond Start Point, Devon and the Channel Islands (Boillot 1965). During the Pliocene the Atlantic probably still extended broadly across the Chalk Downland area of southern England into the S.W. North Sea. Bryozoans, existing in life on a current-swept Chalk sea floor, for instance around the Wealden Island, may well have been re-distributed after death into a belt of hydraulic dunes extending into the S.W. North Sea. Pliocene conditions in southeastern England

and the S.W. North Sea would therefore have compared with those in the Western Approaches and the western English Channel at the present day.

An additional analogy between these two areas is provided by the deep, S.W. - N.E. trending troughs, cut in Chalk and infilled by Pleistocene marine deposits, which exist under East Anglia at the present-day. These troughs are up to 45 to 50 m deep and sometimes over 30 km long (Fig. 1.) In the English Channel at the present day (Boillot 1963) there are three similar troughs, excavated in Chalk in the zone between Start Point, the Channel Islands and the Cotentin Peninsula. They are, with their approximate dimensions:

Central Trough	100 m deep;	165 km long,	6.5 km wide,
Pluteus Trough	20 m deep;	25 km long,	2.3 km wide,
La Hague Trough	50 m deep;	15 km long,	1.8 km wide,
(and for comparison			
Stradbroke Trough	45 m deep;	30 km long,	6.4 km wide)

The analogy between the East Anglian and Channel troughs is striking. Both are excavated largely in Chalk, and both traverse or are adjacent to tracts of bryozoan shelly sands, but are not infilled by them. The origin of neither is clear. The East Anglian troughs have been attributed to tectonic movements involving folding (Woodland 1946), but the higher yields of groundwater obtained from the Chalk between troughs can be just as easily explained in terms of a topographic origin, and S.W. - N.E. trends are not elsewhere typical of East Anglia structures.

Whilst most of the East Anglian troughs appear to be open to the N.E. this may be the result of eastward tilting towards the North Sea during the Pleistocene. The Stradbroke Trough is clearly still closed at both ends. An origin as a 45 to 50 m deep river valley is therefore unlikely, and, what is more, recent boreholes into these

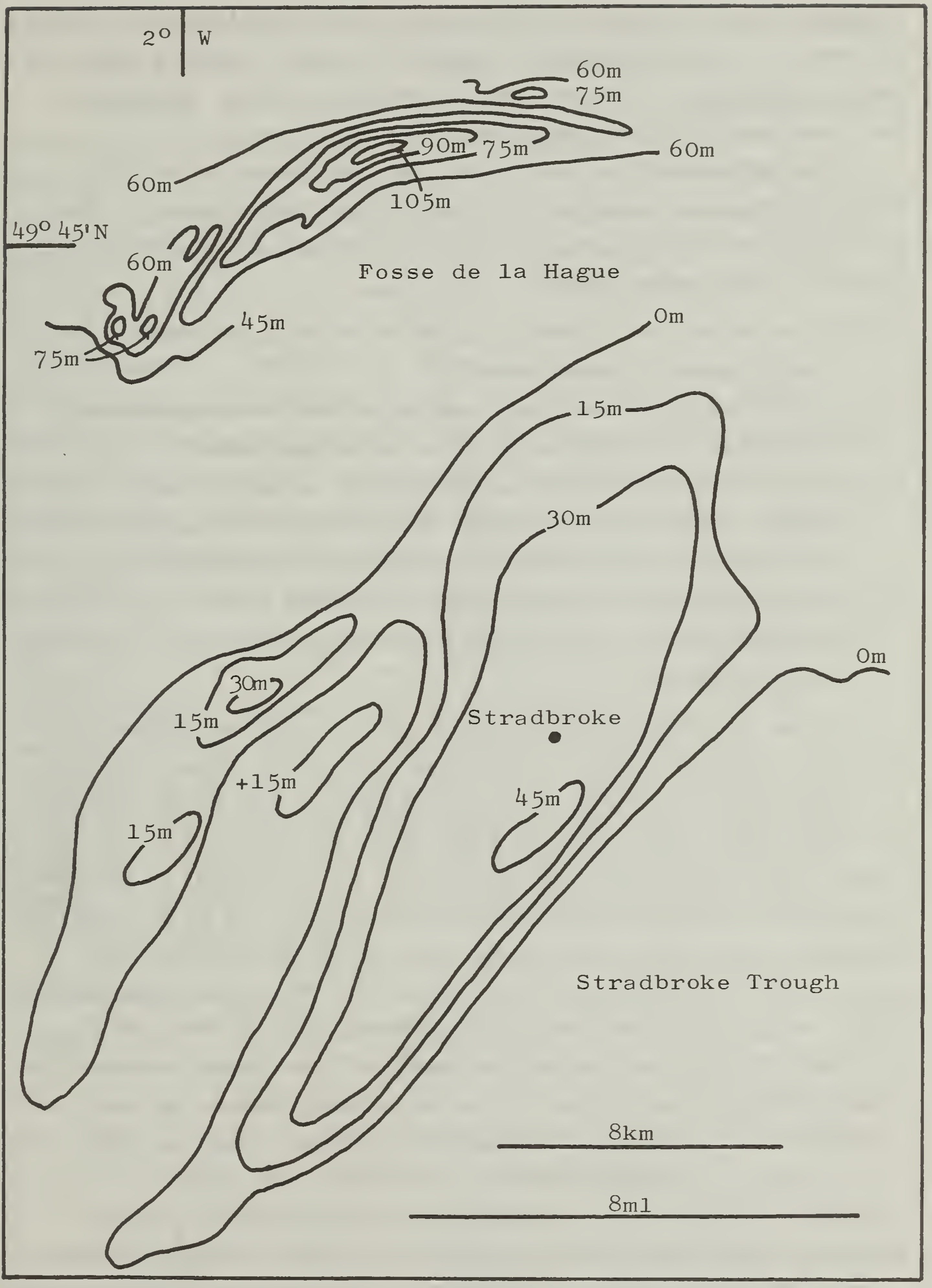

Fig. 1. Comparison of the Plio-Pleistocene Stradbroke Trough with the La Hague Trough (present-day English Channel)

troughs (Lord 1969A,B, 1972) have not revealed any sign of freshwater or terrestrial deposits in the early stages of their infilling. These considerations bring us back to the analogy with the English Channel troughs.

Unfortunately no satisfactory explanation of the English Channel troughs is itself yet forthcoming. Four main explanations have so far been promulgated (Boillot, Bouysse and Lamboy 1971):

(a) that they are drowned river valleys (but they are closed at both ends),
(b) that they are tectonic valleys (but only general relation to structural trends established),
(c) that they have been excavated by present-day tidal currents (but distribution of strongest currents not related to position of troughs),
(d) that they are drowned Karstic forms (but dimensions of the Central Trough would be exceptional).

None of these explanations are wholly satisfactory for the reasons stated. However it may be surmised that in their present form, lacking deposits and being closed at both ends, they are at least maintained by the strong tidal currents active on the floor of the English Channel. A similar situation may be envisaged for the East Anglian troughs, which may therefore have originated and been maintained contemporaneously with the Pliocene Coralline Crag, when the North Sea was probably still broadly open to the S.W. across the dip slopes of the Chalk cuestas. They probably continued to be kept swept clear of any sedimentary infilling during the earliest part of the Pleistocene, but the falling sea-level generally associated with the regressive marine deposits of the Red Crag may have led to their infilling. Certainly the oldest deposits in the Stradbroke Trough appear to be of early Red Crag age, with rapid infilling by Red Crag

deposits reworked from elsewhere at a later stage in the infilling process (Beck, Funnell and Lord 1972).

Whatever the precise origin and mode of infilling of the East Anglian troughs the subsequent pre-glacial history of the North Sea appears to reflect the severance of the southwestward link with the Atlantic Ocean by a general fall in sea-level. After Red Crag times warm temperate species of foraminifer and mollusc, which probably entered predominantly by the S.W. route, are far less abundant. Those few species still found in the Ludham Crag may have migrated, or been maintained by migration, around the north of Scotland before conditions become too rigorous. Thereafter boreal or arctic forms predominate. Also generally thinner shells may reflect less active ingress of water from the open ocean, and relatively higher freshwater inflows leading to rather reduced salinities, after the closure of the S.E. England straits. In this shallow southern North Sea, strongly influenced by sediments from the Rhine-Meuse and the Thames, several climatic oscillations and minor transgressions and regressions of the sea are recorded (West 1961) before the definitive onset of glaciation. These are reflected in the difficult to interpret and complex deposits of the Norwich Crag and Cromer Forest Bed Series (West 1972).

Glacial History

The glacial history of the North Sea is well represented in deposits found on its margins in Norway, Denmark, the Netherlands, Belgium and the United Kingdom, but only recently have investigations of these deposits on the floor of the North Sea been commenced.

A pioneering, yet comprehensive and well-documented account is that of Oele (1969), who describes the sequence of sediments in the S.E. North Sea off the coast of the Netherlands. The succession he recognises commences with

the ELSTERIAN glaciation which is represented by the Peelo Formation comprising fluvioglacial clays. The succeeding Holsteinian interglacial episode is a period of non-deposition on this part of the floor of the North Sea, contrasting with the marginal marine deposits of the Nar Valley, Clacton-on-Sea, etc. found on shore. Relatively shallow-water, marine deposits of this age have however been found in the Inner Silver Pit in the western North Sea (Fisher, Funnell and West 1969). The following SAALIAN glaciation is represented by the Drente Formation, which consists of a boulder clay of Scandinavian origin, and was a period of erosion of the Dogger Bank. The Eemian interglacial was again a period of non-deposition on the bed of the S.E. North Sea, but again marginal marine deposits, e.g. March Gravels, Morston Raised Beach and the Eemian deposits themselves, are well known on shore. The final, WEICHSELIAN glaciation is represented by the Twente Formation which consists of lower and upper fluvial clays with an intervening wedge of fluvio-periglacial coversands.

The dominance of glacial over interglacial deposits in the history of the late Pleistocene of the southern North Sea indicates how much present sedimentary patterns may have been determined by events in the latest glaciation.

In the S.E. North Sea the process of recovery from the last glaciation led to the following sequence of deposits:

Preboreal (up to 9,600 B.P.) Lower Peat

Boreal (up to 8,000 B.P.) Elbow deposits; freshwater clays, passing up into brackish-marine clays and finally sands.

Atlantic (up to 5,300 B.P.) no deposits recognised

Subboreal (up to 2,700 B.P.) no deposits recognised

Subatlantic (up to present-day) Young seasand, in which

the dynamic bed forms relating to present conditions are developed. These reflect both the present tidal current pattern and sources of supply of sediment in the southern North Sea.

The entire Postglacial sequence reflects a transition from terrestrial or freshwater conditions on the bed of the southern North Sea, at the end of the last glaciation, to fully marine conditions at the present time.

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GEOLOGY IN A COLLEGE OF EDUCATION

M. BRADSHAW*

A tutor in a college of education obtains a wider view of the educational field than the individual school teacher, and it is exciting to see the way in which geology is becoming an integral part of the curriculum in so many schools. This process is reflected in the increasing numbers and calibre of students applying for places in the colleges which offer courses in geology leading to honours degrees in education. There are now at least six such colleges; some of these, together with an increasing number of university institutes, offer geology as a method option in the postgraduate certificate course.

Mr. Evans, in his contribution to the September 1971 issue of this journal, was correct in saying that the time has now arrived for an appraisal of the concepts and methods implied in the geology syllabuses taught in the schools. The subject is attaining a status of acceptability, and it must now begin to adopt a more rigorous framework which will make it educationally viable. Those of us working in colleges of education have a privileged position of being able to survey, and to participate in, the developments taking place at the moment.

The most immediate challenge comes from our students teaching the subject in schools. What is the best way to approach the teaching of geology? Where can they obtain the supplies of necessary materials? The topics we discuss with them range from the philosophical working basis of the subject to the practical details of organising a course in the school context. We encourage them to place an emphasis on the field observational basis

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of the subject, linked closely to work in the laboratory or classroom. Our ideas are being refined continuously in the light of ever-widening experience, and will shortly be distilled in 'Teaching Geology', a book which, it is hoped, will appeal to established teachers as well as our own students. David and Charles hope to publish this in 1973.

Most of us would agree that the most significant event in the progress of geology teaching in schools in recent years has been the founding of the Association of Teachers of Geology, and my colleague, Mr. A. J. Dunk, is now the Honorary Secretary. The Association's membership is approaching the 700 mark, it has a lively journal entitled simply, 'Geology', and the annual conference is a 'must' for as many teachers as can possibly attend. The conferences have been held at Keele, Sheffield and Bristol, and combine lectures from eminent geologists, with field excursions, discussions and displays of materials and books. Perhaps their most important function is as a forum for the exchange of views on teaching problems, and the gatherings must be unique in that they bring university professors together with primary school teachers. The Association has been established only for a few years, but has undertaken surveys of the present examination syllabuses, the reports of which have been received by the examination boards. The boards in their turn have requested ATG nominations for membership of their geology panels.

Other important developments in which we are involved concern the place of geology in the overall school curriculum. The close relationship which exists in many schools between geology and geography has been criticised, but we must always be grateful to so many geographers for introducing and teaching our subject

for so many years. And yet geology has its base in close observation and measurement, leading to the formulation of theories and the application of these in practice. In short, it is linked essentially to physics, chemistry and biology. Any discussion of teaching methods must be related to developments in these subjects. For this reason we have been keen to participate in the Schools Council Integrated Science Project, which is designed for the more able pupils at GCE Ordinary Level, and will lead to a double O-level pass for the candidates. Aspects of earth science are established in this course, and the challenge provided by the need to devise investigations and experimental approaches to the subject has been most stimulating.

It seems a logical outcome of such work that further projects of this nature should be developed at Sixth Form level. It is our experience that teachers in school find it difficult to assemble the resources they need for their courses, and so curriculum development projects are not mere gimmicks but have real purpose. Teachers of experience are provided with the time and money to think through aspects of the curriculum and are able to advance the effectiveness of teaching in their subject. Our ideal at the moment is a course in the earth sciences (i.e. broadly including geology, meteorology and ecology). It seems more appropriate to do this than to press the claims of yet another single subject and thus to emphasise the arbitrary boundaries between subjects. One must of course guard against superficiality when including a wider range of subject matter, but the aim of such a course would be to emphasise the working principles rather than the mere acquisition of facts. It seems that the field sciences possess an inherent attraction for students, but there is a need for a more rigorous basis than is provided at the moment by a

largely descriptive physical geography, the normal run of environmental studies, or emotive approaches to pollution and conservation.

Geology is now being seen as a useful integrating element in junior school science courses, and success has been obtained with its introduction as a basic subject in ESN schools. The stress on outdoor observation, together with the emphasis on the laboratory processing of results, appeals at these levels. The history of the earth's development, and the discovery of riches in the minerals of the Earth's crust, are both sources of immediate interest.

In addition to the consideration of what is happening in schools we have to teach the subject to our own students, and this involves mounting courses which take them to a joint honours degree standard. This means that we have a heavy and demanding teaching load, equivalent in time to that of a school teacher. The range of our courses and the fact that our students are intent on a future teaching career means that we attempt to develop our own teaching techniques in this light. When I took up the post I lectured to the groups in a fairly traditional manner, but found that the students imitated this during their teaching practice. Now I attempt to teach even the more advanced material in the sort of way in which it can be introduced to the school classroom. One's ingenuity is often stretched, but the emphasis on a practical, observational and even experimental approach whets the students' interest and sharpens their wits to engage in a discussion of the issues involved. The lecture room full of students is involved, just as the classroom should be in school.

Yet another aspect of the educational process in which one becomes involved is the examination system. It is all very well to grumble about the present system

blighting the school curriculum and the progress of individual pupils, but it is more positive and effective to take some part in making it more suited to the system one would like to see. Through the Association of Teachers of Geology, and our position as college of education lecturers, we have become involved in the development of CSE and GCE syllabuses and assessment. It is encouraging to see the more progressive examination boards producing new, more interesting syllabuses, together with suggestions on the teaching of these and the conduct of field excursions. In this way the examination becomes a logical outcome of the course rather than an arbitrary chopping block, the fear of which has nullified the educational value of the course.

Teaching, writing, examining and thinking about the place of geology in schools is a full-time occupation, and extremely demanding. At times my colleague and I get very tired, but we never lose our sense of excitement at the way in which this situation is developing. New vistas open with developments outside the college, and our own students make their own contributions, whilst our contacts with the schools provide further fuel. We trust that the imminent re-organisation of the colleges of education will not affect the role which we are able to play.

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THE STRATIGRAPHICAL POSITION OF THE NORWICH CRAG IN RELATION TO THE CROMER FOREST BED SERIES

R. G. WEST*

During the last few years the stratigraphy of the Cromer Forest Bed Series had been clarified by the application of pollen-analytical methods to the coastal exposures from Weybourne to Corton. Table 1 summarises the provisional stratigraphical results (West and Wilson 1966).

TABLE 1: Provisional Stratigraphy

Stage	Deposit	Environment	Formerly identified by C.Reid as:
Lowestoftian	i Till	Glacial	Cromer Till
	h Mossy silts, sands	Cold freshwater	Arctic Freshwater Bed
	Ice-wedge casts and involutions	Permafrost	
Cromerian	g Silts, sands	Temperate estuarine, marine	*Leda myalis* Bed, Forest Bed (estuarine)
	f Soil	Temperate	
	e Muds, peats	Temperate freshwater	Upper Freshwater Bed
Beestonian	d Silty marls	Late-glacial freshwater	
	c Silts	Cold freshwater	Arctic Freshwater bed
	b Gravels, sands, clay-conglomerates	Cold	Forest Bed (estuarine)
	Ice-wedge casts and involutions	Permafrost	
Pastonian	a Silts and sands	Temperate estuarine, marine	Weybourne Crag

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Since 1958 a number of pollen samples have been collected from the Norwich Crag (in the sense of Reid 1890) in Norfolk and Suffolk. They include samples from open section, samples from shallow auger holes, and from deep boreholes carried out for water supply purposes. The resulting analyses suggest a new interpretation of the Norwich Crag and its relation to the Cromer Forest Bed Series. We shall first summarise the new evidence, and then consider its bearing on Crag stratigraphy.

The following sites have yielded the evidence to be discussed here. Their locations are shown in Fig. 1, and approximate O.D. heights are given in brackets were possible.

1.	West Runton.	Estuarine silts of Pastonian age (-1m.O.D.).
2.	Sidestrand.	Estuarine silts and marine shelly sands of Pastonian age and Beestonian age (contorted by ice movement).
3.	Paston.	Estuarine silts. Type area for Pastonian temperate stage (-3m.O.D.).
4.	Ludham.	Estuarine silts overlying the Baventian silts and clays (West 1961) (-6m.O.D.).
5.	Outney Common, Bungay.	Estuarine silts and shelly gravels (-3m.O.D.).
6.	Thorpe Aldringham.	Shelly sands with silts (+3m.O.D.).
7.	Aldeburgh.	Shelly sands with thin silts (+4m.O.D.).
8.	Chillesford.	Sands with few shells and thin silts (+9m.O.D.).

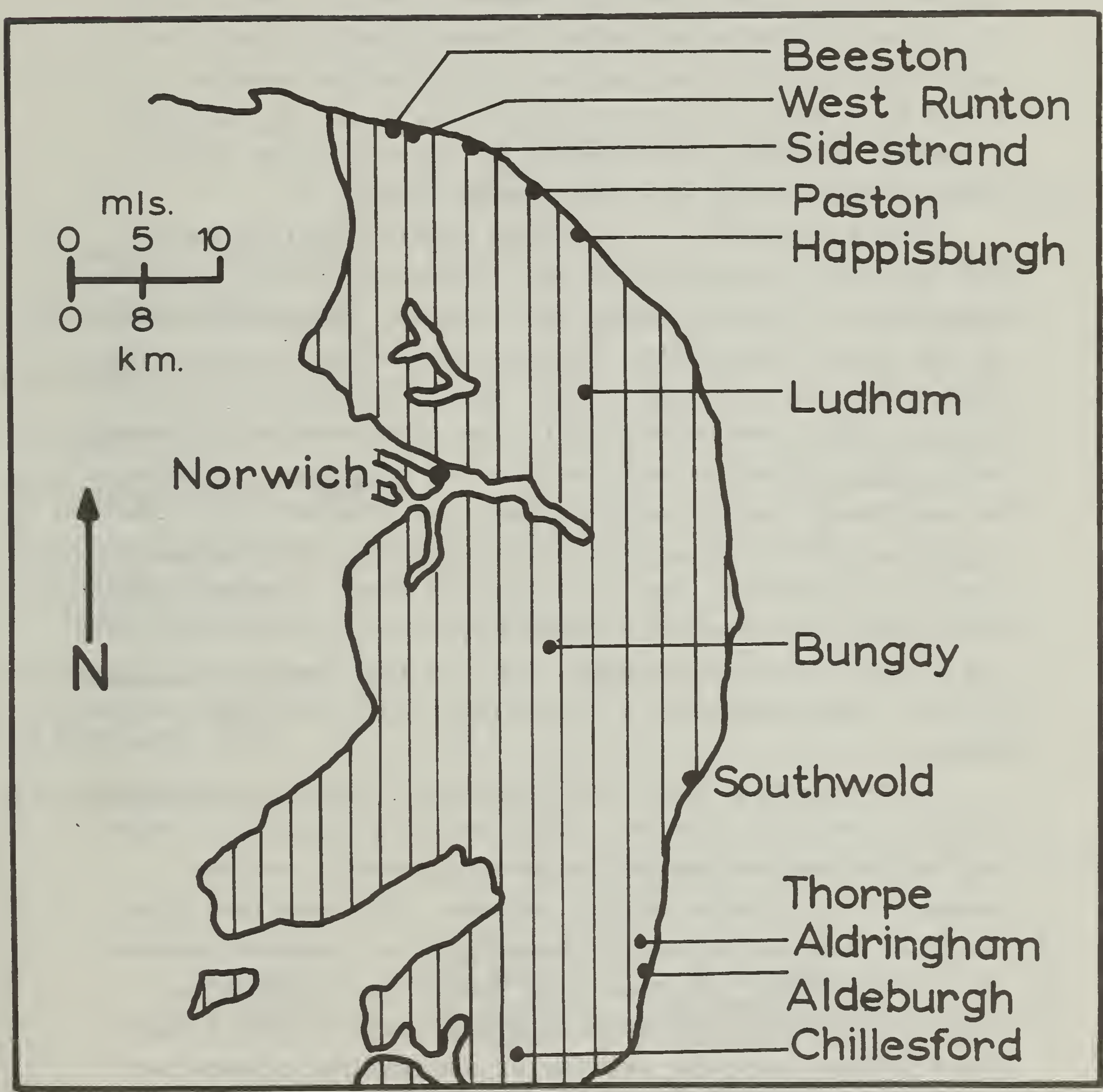

Fig. 1. Location of Sites

At the first three sites, the sediments mentioned are of Pastonian age. They all have temperate pollen spectra of the type exemplified in Fig. 2. A series of pollen spectra from zone L5 of the Ludham borehole (West 1961) and from a borehole at Outney Common, Bungay, have the same type of spectrum, and so do the pollen samples taken from open section at sites nos. 7 and 8, and from a shallow borehole at site no. 6. Spectra from these sites, nos. 4 to 8, are also shown in Fig. 2.

The similarity of all these spectra will be noted. But they are dissimilar to the temperate spectra from the Cromerian on the one hand, and from the temperate stages of the Early Pleistocene (Antian, Ludhamian) on the other hand. The major dissimilarity to the Cromerian lies in the fact that the estuarine facies of Cromerian contains much _Abies_ pollen as well as that of _Carpinus_. It should be mentioned that at West Runton, the type site for the Cromerian, the Pastonian is stratigraphically distinct from the Cromerian, and is separated from it by an arctic plant bed and permafrost features. The dissimilarity with the earlier temperate stages lies in the absence of _Tsuga_ pollen, characteristic of the Antian and Ludhamian temperate stages.

A conclusion which might be drawn from the pollen spectra obtained from the sites under discussion is that the marine and estuarine deposits concerned are the products of a single marine episode. The similarity of the O.D. heights of the different sites tends to support this conclusion. In time this transgression must be placed between the Beestonian and Baventian cold stages. The evidence for this placing of the marine episode is the superposition of Beestonian sediments at West Runton, Sidestrand, and Paston, and the infraposition of the Baventian at Ludham (West 1961).

Now the shelly gravels or sands from which the pollen

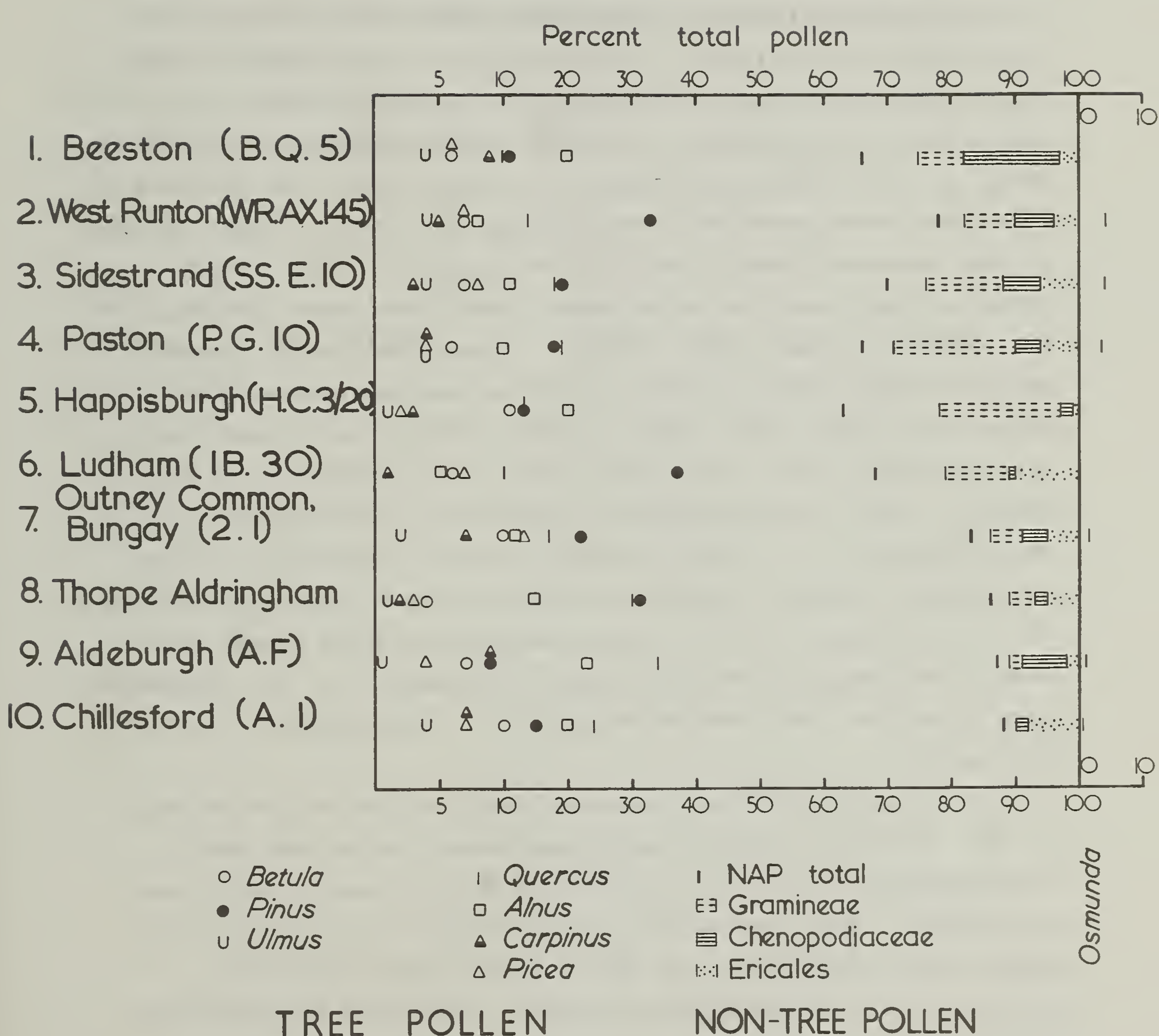

Fig. 2. Pollen spectra

samples come at Bungay, Thorpe Aldringham, and Aldeburgh are the classic sediments of the Norwich Crag, while those at Chillesford have been described as Chillesford Clay and Crag, and those at Sidestrand as Weybourne Crag. We therefore conclude that the Norwich Crag, Chillesford Crag and Weybourne Crag at the sites studied are probably all deposits within the temperate Pastonian stage. To the north the sediments overlap basal stone beds on the frost-shattered chalk, probably of Baventian age. To the south the sediments overlap the Red Crag and Coralline Crag in the Aldeburgh region. We thus have the picture of a marine transgression overlapping the older Crags in much of the coastal Crag area in East Anglia. This transgression may also be associated with the beach gravels of the Westleton Beds (Hey 1967). These Pastonian transgression deposits probably overlie unconformably the Baventian silts and clays, as the latter are absent in many sections and boreholes. They are overlain on the Norfolk coast by freshwater regression deposits and, unconformably, by the freshwater arctic deposits of the Beestonian stage. Further, there is some indication from the O.D. heights of the sites mentioned that there has been upwarping of the Pastonian sediments in the southern margin of the Crag basin relative to the central part of the basin.

Much more work is required before the stratigraphy of the different shell beds considered here and their overlapping relation to the older Crags can be made out in detail. But, meanwhile, the evidence described here makes the consignment of the various Crag horizons mentioned to the Pastonian stage a definite possibility, which will considerably simplify the Crag sequence of East Anglia.

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A PRELIMINARY ACCOUNT OF A RESEARCH BOREHOLE AT SYLEHAM, SUFFOLK

A. R. LORD*

Initial accounts of our previous research boreholes undertaken in an investigation of the Lower Pleistocene have already appeared in the Bulletins of this Society. The present note describes the findings of a fifth borehole, the last in the current series. Some results from the Stradbroke Borehole (UEA 3) will appear shortly in the Geological Magazine.

Borehole UEA 5. High Elm, Syleham, Suffolk (TM 2095 7833) - located beside the East Anglian Water Company's pumping station

Drilled in October, 1970. Surface level 139.48' (42.51m) O.D. The borehole was made close to the pumping station, where a number of boreholes had been drilled by the East Anglian Water Company for water supply purposes. The earlier boreholes provided valuable stratigraphic information and, particularly important, a number of samples which included a peat from 105-108' (32.0 - 32.9m.) below surface and sands containing excellent assemblages of foraminifera. The water bores gave the following general succession:

0' - 3'	(0 - 0.9m.)	Top soil and brown clay
3' - 21'	(0.9 - 6.4m)	Blue clay
21' - 55'	(6.4 - 16.7m.)	Sand with a little gravel
55' - 69'	(16.7 - 21.0m.)	Gravel with a little sand
69' - 91'	(21.0 - 27.7m.)	Fine brown sand
91' - 100'	(27.7 - 30.5m.)	Gravel with flints
100' - 105'	(30.5 - 32.0m.)	Green sand
105' - 108'	(32.0 - 32.9m.)	Peat
108' - 181'	(32.9 - 55.1m.)	Green sand

(continued)

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181' - 185' (55.1 - 56.3m.) Sandy brown clay
185' - 216' (56.3 - 65.8m.) Blue clay
216' - 222' (65.8 - 67.6m.) Hard green sand
222' - 231' (67.6 - 70.4m.) Blue clay and flints
231' (70.4m.) Chalk

The succession found in the research borehole is shown in Fig. 1 and is generally comparable with earlier findings, although it should be noted that since the water bores were drilled by a reversed circulation technique their data is less reliable. The grey and brown chalky boulder clay at the top of the sequence is thought to be Lowestoft Till, although the till encountered in the Stradbroke and Hoxne Boreholes (UEA 3 and UEA 4) was more uniformly blue-grey in colour. Beneath the till occurred coarse gravels and sands, and at 71' (21.6m.) depth sands which were clean washed with small pieces of chalk, which may indicate that they are "Corton Beds" and that the coarser material above is of glacial origin. At 100' (30.5m.) depth the sands became green and are interpreted as the Norwich Crag Series even though shell material did not occur above 139' (42.3m.). Beneath this depth the quantity of shell increased but complete shells were never very common. Below 193' (58.8m.) silty clay layers became common, but it was not before a depth of about 220' (67.0m.) was reached that it was possible to consider the argillaceous material as forming a unit of hard silty clay. A thin band of flints was found to rest on the chalk surface which was reached at a depth of 229' (69.8m.) below surface.

The research borehole proved a good sequence of 'Crag' sands and clays between 100' (30.5m.) and 229' (69.8m.), which first samples show to contain fine assemblages of diatoms and foraminifers. It was unfortunate, but not unexpected, that the peat layer was not found but the

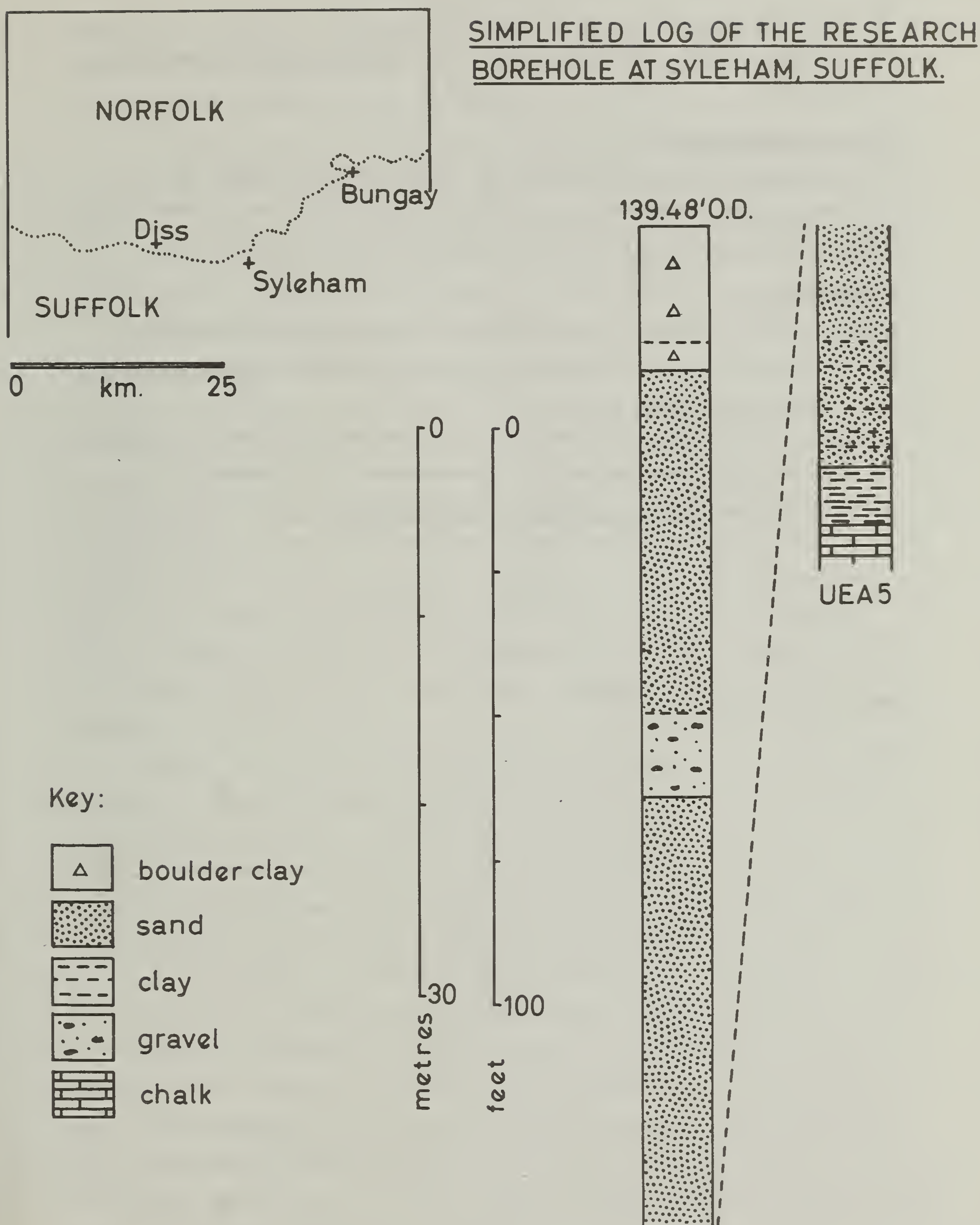

Fig. 1. Log of research borehole at Syleham, Suffolk (UEA 5)

foraminfers may provide some clue as to conditions at that time.

Acknowledgements

The co-operation of Mr. I. B. Wingfield of Home Farm, Syleham, the landowner, and Mr. K. B. Clarke of the East Anglia Water Company is gratefully acknowledged.

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REPORT ON A FIELD MEETING TO THE NORFOLK COAST AT YARMOUTH AND OVERSTRAND

S. J. CRAIG-SMITH and G. CAMBERS*

On Sunday 19th September 1971 a field meeting was held to examine some of the erosion problems along the Norfolk coast. The party assembled by the yachting pool (bottom right of Fig. 1) on Gorleston Beach at 11 a.m. and was given an outline of the erosional history.

Gorleston beach lies immediately south of Yarmouth harbour entrance which is the outflow of the rivers Yare, Waveney and Bure, the only major river system in Norfolk. The beach extends south from the harbour to Yarmouth borough boundary, a distance of approximately 1.7 kilometres. Its width today varies from about 80 metres at its northern end to 50 metres at its southern end (limit of low water spring tides) but this is less than half its width in the early 1960's. Backing the beach for its entire length is a concrete wall and behind that Gorleston cliffs, 20 metres high, artificially sloped and turfed.

Prior to 1962 Gorleston beach showed little sign of erosion. Beach levels dropped after severe storms but the beach was soon restored to its original volume. Since that date however, there has arisen a serious problem of erosion which shows no sign of abating. By 1965 erosion had become sufficiently serious for the Borough Engineer to consult the Hydraulics Research Station which conducted a survey the following year (Hydraulics Research Station 1966). In December 1969 14,000 cubic metres of sand was injected onto the beach near the yachting pool (a remedial measure suggested by the Hydraulics Research Station) but this had only a temporary effect. In 1970 the Borough Engineer asked the School of Environmental Sciences at the University of East Anglia to carry out a three year research programme

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Fig. 1. Aerial view of coast - Gorleston to Caister

(Craig-Smith 1971A, B, C) into all the environmental factors, not only at Gorleston, but along the entire coast from Winterton in Norfolk to Benacre in Suffolk. (This project is also being sponsored by Lothingland Rural District Council and Lowestoft Borough Council.) As part of the analysis early maps of Gorleston beach were consulted.

A number of interesting points arise from an examination of old maps of Gorleston beach. The earliest reliable map of the beach is the first edition of the O.S. 6 inch map (1:10,560) surveyed in the early 1880's. Earlier maps exist but their scale is too small and their cartographic accuracy must be regarded with caution (Carr 1962). On this map the high water mark is shown landward of its present position in spite of the very considerable landward advance of this water mark over the last few years. The 1900's edition of the same scale map shows the high water mark to have advanced seaward 75 metres immediately south of the harbour mouth. The 1930's edition shows another advance putting the high water mark 100 metres seaward of its 1880's position. Accretion then slowed down but continued, for the 1950's edition shows high water mark 110 metres seaward of its first recorded position. Since the 1950's the high water line has receded very rapidly reverting to its 1880's position in under 20 years (Fig. 2, map 1A). This suggests that on Gorleston beach there has been a long phase of accretion (70 years) followed by a recent trend of very rapid erosion (under 20 years and pronounced only in the last 10 years).

This cartographic evidence is supported by the existence of a series of groynes recently exposed after being buried in the sand since the 1890's. The considerable losses of sand in December 1970 finally

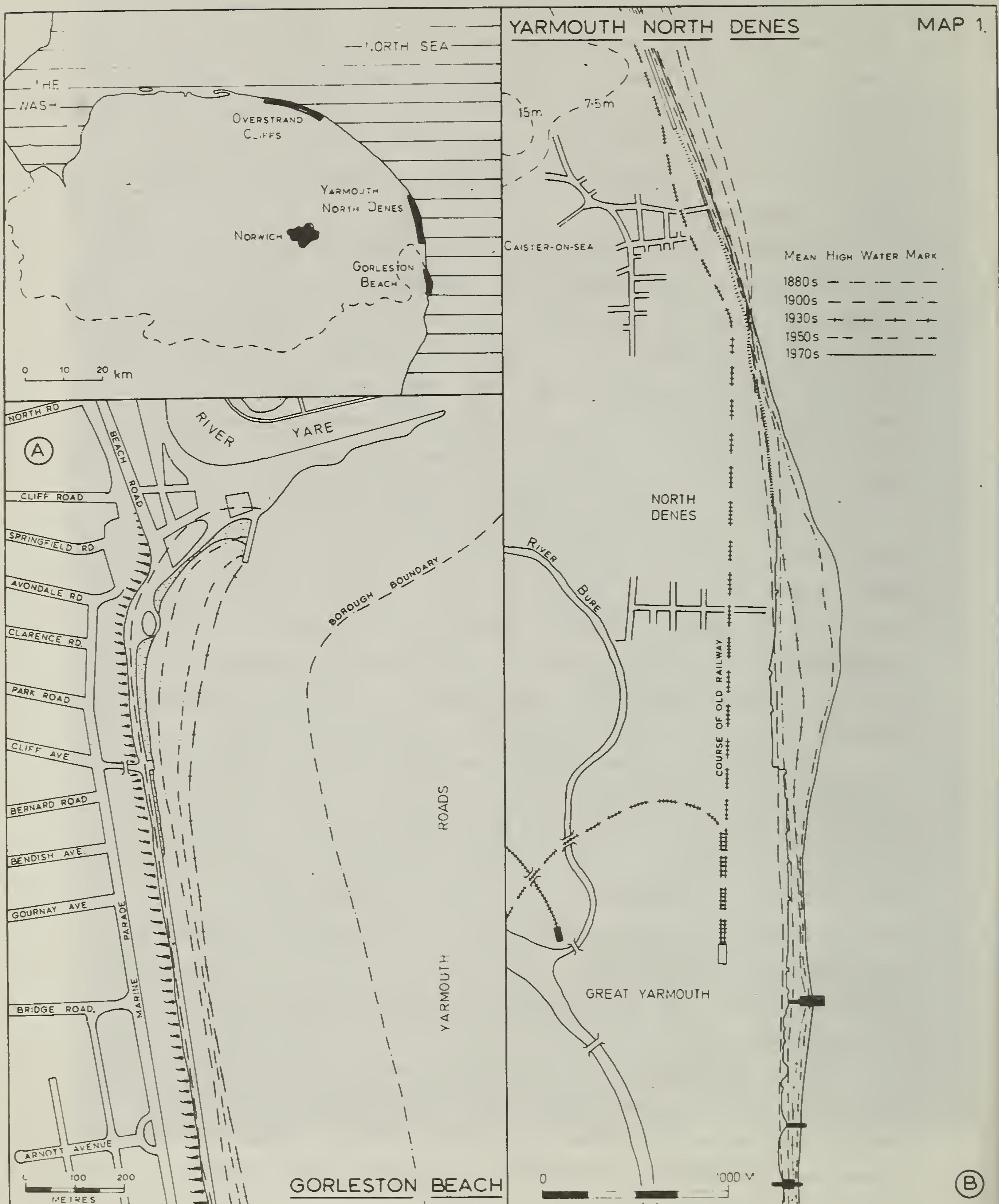

Fig. 2. Map of coastal changes - Gorleston to Caister

exposed these groynes. In the 1966 H.R.S. Report it states ".....it has been suggested that a number of old groynes lie buried in the beach." If the present erosionary trend continues these groynes may soon be washed away. These groynes however, indicate that beach levels in the 1890's were no higher than they are today.

These findings pose a number of problems, the first being why Gorleston beach accreted 110 metres between 1880's and 1960's. Secondly, after this accretion why did erosion start in the early 1960's? The most generally accepted answer, particularly held by local people, is that the new South Pier to Yarmouth harbour is now in solid concrete, whereas its predecessor was of an open wooden structure which allowed sediment transport southwards from Yarmouth beach. The fact that this new pier was built in the early 1960's when serious erosion first began could be more then coincidence, but other factors so far ignored could all play a cumulative part. The change in the offshore configuration (i.e. change in position and depth of channels and sand banks), together with the frequency of easterly winds within the last 10 years must all be examined. It is not possible at this early stage to state exactly what process plays which part in the accretional/erosional history of Gorleston beach, but natural phenomena are rarely, if ever, a product of just one process.

The party then went onto the beach to examine the exposed toe piling of the yacht pond and the remains of the old groynes exposed earlier in the year. An examination was made of the pebbles on the beach and then the party moved north to Yarmouth North Denes (top centre of Fig. 1) outside the Iron Duke Hotel.

In marked contrast with Gorleston beach, Yarmouth North Denes only 5 kilometres to the north is an area of

local continuous accretion showing a net gain of approximately 2.25 million cubic metres of sand since the 1880's (Fig. 2, map 1B). Between the 1880's and 1900's the beach was accumulating at 0.7 metres per annum, but this increased to 2.7 metres between 1900 and and 1930's. Since the 1930's accretion has slowed slightly but is still 2.5 metres annually. The sea wall constructed in this area in the 1930's has never been reached by the sea in normal conditions.

According to Robinson (1966) the reason for this local accumulation lies in the offshore configuration. Caister Shoal lies offshore; this is a long narrow sand-bank trending towards the coast at the Denes area. Thus sediment movement, which normally takes place parallel with the shore, trends towards it at this point and then wave action can move the sand onto the beach. After a brief examination of the beach the party stopped for lunch before proceeding to the North Coast.

The afternoon was devoted to a consideration of the erosion problems on the cliffed section of the North Norfolk Coast. The cliffs extend from Weybourne in the west to Happisburgh in the east - a distance of 30 kilometres. They are composed throughout of glacial material, and were deposited during the Lowestoft Stage of the upper Pleistocene. The glacial material lies on top of the Chalk, which dips to the east; hence between Weybourne and Sheringham the cliff base consists of solid chalk. At Sheringham the Chalk is at sea level, and so disappears from view further east, except for occasional exposure of the old chalk platform on the beach, when sand levels are low due to erosion by waves.

The cliffs exhibit a considerable range, both in composition and height. Many attempts have been made to work out the geological succession - perhaps the number

of these attempts indicates the complexity of the field evidence. One of the most detailed accounts is given by J. D. Solomon in his paper of 1932. As regards cliff height the range extends from 22 metres at Weybourne, to a maximum of 70 metres at Trimingham, and declines again to 10 metres at Happisburgh.

This length of coast shows a picture of continual erosion, unlike the coast further south where, as explained in the morning, Gorleston beach has shown phases of erosion and accretion at different times. The erosion has been calculated from the changed coastline position as shown on the 6 inch O.S. maps (1:10,560) over the past 80 years. This provides us with a mean figure of 0.8 metres retreat per annum. However, this figure masks a considerable variation, and the following table shows a more detailed picture of the erosion rates.

STRETCH OF COASTLINE	DISTANCE (km)	RETREAT RATE (m/annum)	CLIFF HEIGHT (m)
Weybourne - Sheringham	4.03	0.41	26.17
Sheringham - Cromer	5.08	0.43	30.00
Cromer - Overstrand	2.60	0.46	53.10
Overstrand - Trimingham	2.42	1.63	49.40
Trimingham - Mundesley	3.22	1.01	25.00
Mundesley - Happisburgh	9.80	0.94	21.32

The cliffs from Overstrand to Trimingham show the highest rates of erosion, and it is also here that the cliffs attain their greatest height. However, before concluding that these two facts are linked, one must also take into consideration the relatively high retreat rate of the cliffs between Mundesley and Happisburgh (0.94 metres per annum) yet this is an area of very low

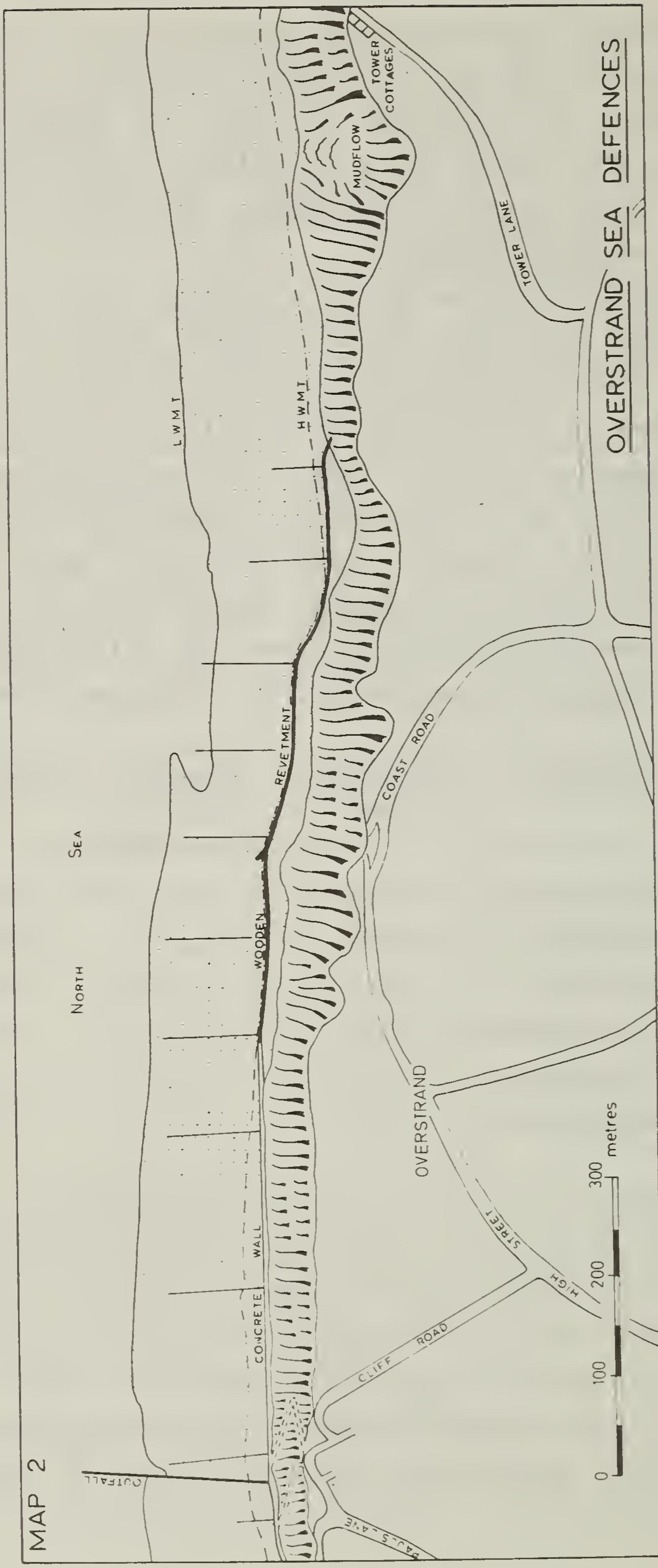

Fig. 3. Overstrand sea defences

cliffs so therefore......? Hence we must conclude that any relationship will inevitably be complex - including such factors as types of erosion processes, geology of the cliffs, beach height, and offshore configuration - thus providing a multivariate situation which requires complex analysis techniques. Present work is being directed into evaluating the relative importance of these factors.

The volume of material removed from the cliffs each year is 750,000 cubic metres. This compares with the figure of one million cubic metres per annum for the erosion of the Holderness coastline - a 61 kilometre length of cliffs in Yorkshire, again in glacial materials (Valentin 1971). The material from both coastlines will be deposited in the North Sea.

At Overstrand itself the erosion problems are particularly severe. The most important factors causing the high erosion here are the number of underground streams issuing out of the cliffs (these help to initiate cliff falls and mudflows), the inherent weakness of the glacial material, and the low beach - which allows the sea to reach the cliff base at high tide and to remove any debris that has accumulated there. Thus this represents an extremely efficient erosion system, with a virtually constant supply and unimpeded removal.

The party examined the cliffs at Overstrand, and discussed the attempts that had been made to defend them. The coastal defence works (Fig. 3, map 2) consist of a wooden revetment, which is designed to prevent the waves attacking the base of the cliffs, and which together with the groynes is meant to promote beach development. In addition there is a concrete sea wall in front of the village itself, and the remains of an old sea wall which was destroyed in the 1953 storm surge are exposed on the

beach - for at present the sand level is very low. The second part of the sea defence scheme is concerned with an attempt to drain the cliffs - however, here problems are encountered due to the fluctuating nature of these underground streams.

Indeed the party observed a number of these streams emerging from the chalk erratics near the eastern end of the defences. It was also noticed that they were red coloured - due presumably to their iron content. Towards Sidestrand further streams were seen to emerge from the cliffs at many different levels.

As the party walked along the beach behind the defences, it was observed how previous high tides has scoured out the beach behind the revetments, so that now high tides can attack the cliffs themselves - thus emphasising the temporary nature of these defences. And indeed, from the east Overstrand may be observed to project out like a headland - this is the result of coastal protection at one point only, while adjacent sections remain unprotected and hence erosion is concentrated here - resulting eventually in a headland.

At one point, just west of Tower Cottages, Sidestrand (G.R. 258403) the party climbed up the cliff to view a large mudflow which had developed in the site of an old rotational slip (Fig. 4). Discussion ranged over the relative importance of cliff falls, mudflows, stream erosion and other processes taking place.

After this the party broke up. It had originally been planned to visit Mundesley where sea defence works have proved more effective, however time did not allow, so just a brief reference was made to this site.

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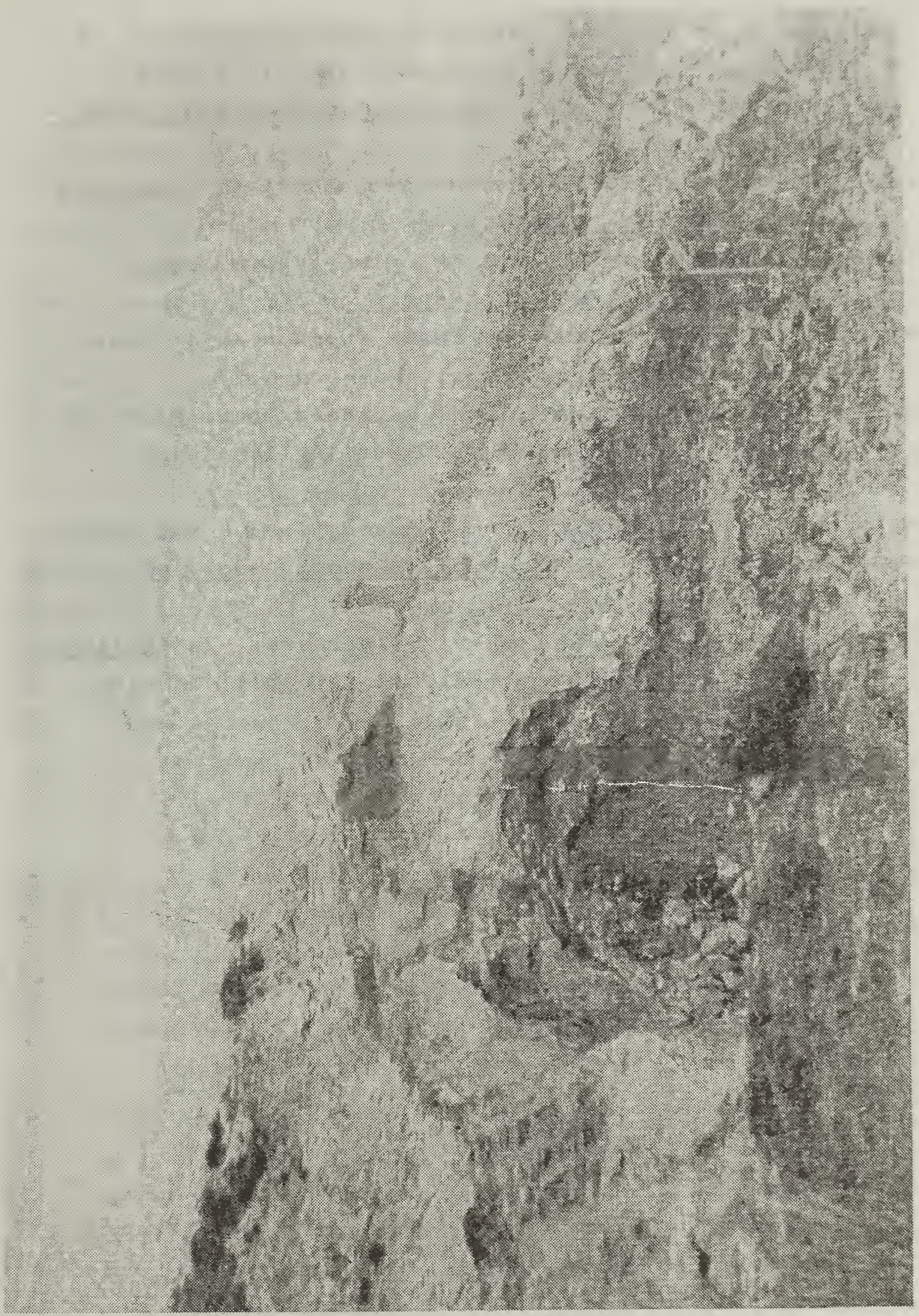

Fig. 4. Mudflow on site of old rotational slip - Sidestrand

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REPORT ON FIELD MEETING TO THE NORFOLK COAST

(Joint Meeting with the Conchological Society of Great Britain and Ireland)

P. G. CAMBRIDGE*

The purpose of this meeting, on August 8th 1971, was to examine and collect from a series of sands occurring in the tills of the Norfolk Coast. The first of these was at California Gap (TG 518417) where a series of sands occur between two tills or boulder clays. Near the base, these sands are often rich in shell fragments and members collected a good representative series. The sand beds are probably a northern extension of the Corton Sands. Many of the shells are well known from the earlier Crag series, such as *Scaphella lamberti* (Sowerby), *Turritella incrassata* (Sowerby), *Astarte omalii* Lajonk, etc., but with them are considerable numbers of *Macoma balthica* (Linné). The 'Cortonian' fauna has been the subject of much controversy over the years and three possible origins have been suggested:

1. That the whole fauna lived in the area and that the 'warm water' forms, which had been wiped out by an ice advance, re-occupied the area from elsewhere. In support of this argument certain species were cited which were not known in earlier Crag beds. One of these species has since been found in the Ludham Crag and others seem to have been based on small possibly immature forms, or protoconchs. Since the original specimens are not available, it seems best to ignore these earlier records and concentrate on accurate collecting.

2. That the deposit was formed partly from the destruction of Crag beds of several ages during a temporary regression of the ice front and that all the shells are derived.

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3. That some forms were derived from earlier Crag and that these are mixed with an indigenous fauna. Certainly the forms characteristic of the earlier Crags are usually very fragmentary and worn.

After driving over a large area of low-lying silty ground, bordered by sand dunes, the next area of higher ground was reached. The party descended the cliffs near Mundesley (Little Marl Point, TG 300378) in the hope of locating shelly layers in the Gimingham Sands. Although this was unsuccessful, shell fragments were seen in a typical boulder clay, including Cardium (Cerastoderma) edule L, Arctica islandica (L) and Macoma balthica. A small chalk bluff at the base of the cliff was examined and some members collected Maastrichtian Chalk fossils here.

The last stop was at West Runton Gap (TG 185431) where the party first examined the sands in the large basin to the west of the Gap. The mode of formation of these large sand basins is not fully understood; they may or may not have been formed at the same time as the large spreads of Corton Sands to the south. Near the top of the basin a layer of large flints was seen and from this a number of flat, rounded pieces of ironstone, a piece of heavily mineralised fossil wood, and a fragment of deer antler, were taken. For about two metres below this pebble bed the current bedded sands contain large numbers of worn shells and shell fragments. The majority of the shells are the same species as those found in the clays of the North Sea Drift but in addition Red Crag shells such as Nassarius reticosus (Sowerby) form costatus (Wood) have been found, as well as extremely thin and fragile freshwater shells. On this occasion an example of the Cromerian Valvata goldfussiana (Kennard) was found. The ironstone, deer antler and freshwater shells could all be from the Cromerian period.

For the remainder of the time available members split up into groups, to browse either on the dark humic clays of the Lower Freshwater Bed or on the Stone Bed of the Weybourne Crag. The former is exposed at the base of the cliffs and is the type site of the Cromerian, and yields a selection of plant material, freshwater shells, fish teeth, etc. The large flints of the Stone Bed commonly trap worn sea-urchin casts and belemnites from the Chalk, mixed with beds of modern *Mytilus edulis* and some striking red and orange coloured *Nucellas* and *Littorinas*.

Received January 1972

CONTENTS

The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may apply for election to the society. For further details write to the Secretary, Castle Museum, NORWICH, NOR 65B.

Copies of this Bulletin may be obtained 60p (post free) from the Society at the Castle Museum, NORWICH, NOR 65B; it is issued free to members.

Also available at 75p (post free) is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 22

CONTENTS INCLUDE:

Last interglacial mammals
Molluscs and pollen from the Crag
Geology at Gresham's School
Geology textbooks for schools
Hunstanton and West Runton field meetings

BULLETIN of the GEOLOGICAL SOCIETY OF NORFOLK
No. 22 September 1972
Editor: R. S. Joby
116 Gowing Road, NORWICH, NOR 40M

EDITORIAL

Included in this issue are the previously promised articles on molluscs and pollen from Aldeby, and mammals of the last interglacial in Norfolk. Continuing our series on Geology in education, Mr. Coleman of Gresham's School, Holt, gives his view on the subject in public schools, and the editor contributes a review of currently available textbooks. It is hoped to publish an article on Geology in the Open University in the next issue.

Bulletin No. 23 will be issued in April 1973. Contributions should be sent to me as soon as possible, and no later than January 31, 1973.

Will contributors please note that manuscripts are acceptable in legible handwriting, although typewritten copy is preferred. In either case it would be a great help if details of capitalisation, underlining, punctuation, etc., in the headings and references (particularly), could conform strictly to those used in the Bulletin. Illustrations intended for reproduction without redrawing should be executed in fine, dense, black ink line. Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations should, before reproduction, fit into an area of 225 mm by 175 mm; full use should be made of the second (horizontal) dimension, which corresponds to the width of print on the page, but the first (vertical) dimension is an upper limit only. Can all measurements be in metric units, please.

R.S.J.

MAMMALS OF THE LAST INTERGLACIAL IN NORFOLK

B. McWILLIAMS*

Mammalian remains have been found from six sites in Norfolk thought to be of Ipswichian age - Mundesley, Wretton, Beetley, Wortwell, Shropham and Swanton Morley. West (1961) noted the correlation of this period and the Morston raised beach, the likelihood of the Mundesley 'river bed' being Ipswichian, and the discovery of the Wretton site. In the last decade four more sites have been discovered with mammalian remains which are now in Norwich Castle Museum. (The location of the Norfolk sites is shown in Fig. 1.)

1. Morston

Between Morston and Stiffkey at the edge of the marshes is what Solomon (1932) describes as a raised beach, the top at about 7 metres above O.D.

Exposures on both sides of the River Stiffkey show about 1 metre of beach, overlain by 1 metre of weathered Hunstanton till on which Mesolithic flint tools have been found. More recently (Baden-Powell and West 1960), there has been a suggestion that the site may represent a small glacial marginal drainage feature. However it resembles a beach deposit more closely except that the pebble orientation has been changed towards the vertical by cryoturbation.

No fossils have been recorded from the beach, perhaps not unexpectedly in such a high energy environment, and it is presumed to be Ipswichian on stratigraphical grounds alone.

2. Mundesley

Cut into the drift and exposed in the cliff for many years, though now obscured by a sea wall, is the Mundesley 'river bed' described by Reid (1882) as a "thick lenticular

* Castle Museum, NORWICH

KEY

1	Morston	5	Swanton Morley
2	Mundesley	6	Wortwell
3	Wretton	7	Shropham
4	Beetley		

Fig. 1. Last Interglacial sites in Norfolk

mass of peaty loam with plant remains, shells, bones and elytra of beetles". Following the sinking of boreholes by the Cambridge Sub-Department of Quaternary Research in 1970, pollen studies (Miss L. Phillips, personal communication) have proved it to be Ipswichian. The vertebrate fauna includes _Palaeoloxodon_ (_Elephas_) _antiquus_ and _Emys lutaria_, the European pond tortoise, both in Norwich Museum.

3. _Wretton_

The 1961 excavations for the Fen flood relief channel exposed Ipswichian deposits at Wretton. Apparently few bones were found from the interglacial here, but the stratigraphy, palaeobotany and non-marine mollusca were studied in detail (Sparks and West 1970). Later deposits are to be the subject of a forthcoming publication and include vertebrate remains (West, Sparks and Joysey 1972).

4. _Beetley_

Near East Dereham in 1964 gravel workings exposed organic deposits rich in mammalian remains which are now in Norwich Castle Museum (accession no. 383.964) and were described by Markham (1966, 1967). They include the following: _Hippopotamus amphibius_ L., _Palaeoloxodon antiquus_ (Falc. and Caut.) _Cervus elaphus_ L., _Megaceros giganteus_ (Blum.) and a species of bison and rhinoceros. Although prominent, the hippopotamus bones belong to a single individual only. Palaeobotanical studies (Miss L. Phillips, pers. comm.) place the hippopotamus in Ipswichian zone f (IIb) (West 1968), the mixed oak forest zone with high tree pollen and no evidence of much open ground.

5. _Swanton Morley_

In November 1969 a gravel pit at Swanton Morley yielded organic beds rich in plant remains, molluscs and bones. Sediment samples from bones of _Hippopotamus amphibius_ L., _Bos primigenius_ Boj. and a molar of

Palaeoloxodon antiquus (Falc. and Caut.) were analysed for pollen at Cambridge Sub-Department of Quaternary Research. Hippopotamus and Bos belonged to Ipswichian zone g (III), the hornbeam zone, whilst the elephant was assigned to the later part of zone f (IIb). All eleven samples showed evidence of open ground with a high proportion of grasses, Plantago lanceolata (a grazing indicator) and Compositae (Miss L. Phillips, pers. comm.). As at Beetley, hippopotamus is represented by a number of associated bones of one individual. The fauna also includes voles (Clethrionomys and Microtus), mouse (Apodemus) and a single tooth of fallow deer, Dama dama (L.) (A.J.Stuart, pers. comm.)

6. Wortwell

In 1967 workmen digging a sewer trench at Wortwell Low Road uncovered part of the skeleton of a Straight-tusked Elephant, Palaeoloxodon antiquus (Falc. and Caut.). This site was the subject of a paper by Sparks and West (1968) who showed the presence of earliest Ipswichian, zone c (Ia), zone f (IIb) and the absence of zone g (III). The elephant remains were later sampled for pollen by C. Turner (1970, pers. comm.) to locate them in the published sequence of samples, indicating an environment of standing or slowly moving water some half to three or four metres deep in open conditions. A pit some 35 metres away, in the adjacent gravel terrace, has yielded mammoth, rhinoceros, reindeer, horse and bison (in Norwich Castle Museum) of presumed Gipping age.

The elephant remains comprise one incomplete and three complete molars, parts of the skull, jaw and tusks, and right fore-foot spread over an area of a six metres square at a depth of 4.5m. More extensive excavation was impossible as the site was below the highway and adjacent to a dwelling-house.

One molar, a lower left third (Castle Museum no.

877.967(3)) shows certain abnormalities (Fig. 2). The anterior half of the molar is displaced buccally, beginning at the 7th lamellae out of 13 in wear. There are similarities with a Forest Bed Series P.antiquus molar described and figured by Wells (1969). The lingual surface has a broad pit penetrating enamel and dentine at about the margin of the gum. Anteriorly there is an abraded area strongly suggestive of a 'push-facet' produced during expulsion of the neighbouring tooth. The buccal surface has a sharp-edged slot, again at the margin of the gum some 70 mm long, 15 m wide and 10 mm deep. This latter feature may represent the site of an infection, as it is present at a third site at the gum margin of the incomplete lower right molar. The occlusal surfaces of all four teeth show no clear evidence of function disturbance.

7. Shropham

In October 1969 the Ipswichian date of deposits previously exposed in a gravel pit at Shropham was indicated on examination of many bone finds on the site. No organic beds are now exposed but notes by R. R. Clarke in Norwich Castle Museum dated 17.7.56 give the following section, the lower part obtained by boring, with the comment "?interglacial"

Lithology	Thickness (m)	Depth (m)
topsoil	0.3	0.3
sands	4.6	4.9
peat	1.0	5.8
gravel	6.0	11.8
peat	1.2	13
sand	1.0	14
dark mud	3.0 +	17 +

Surface at 24 m O.D.

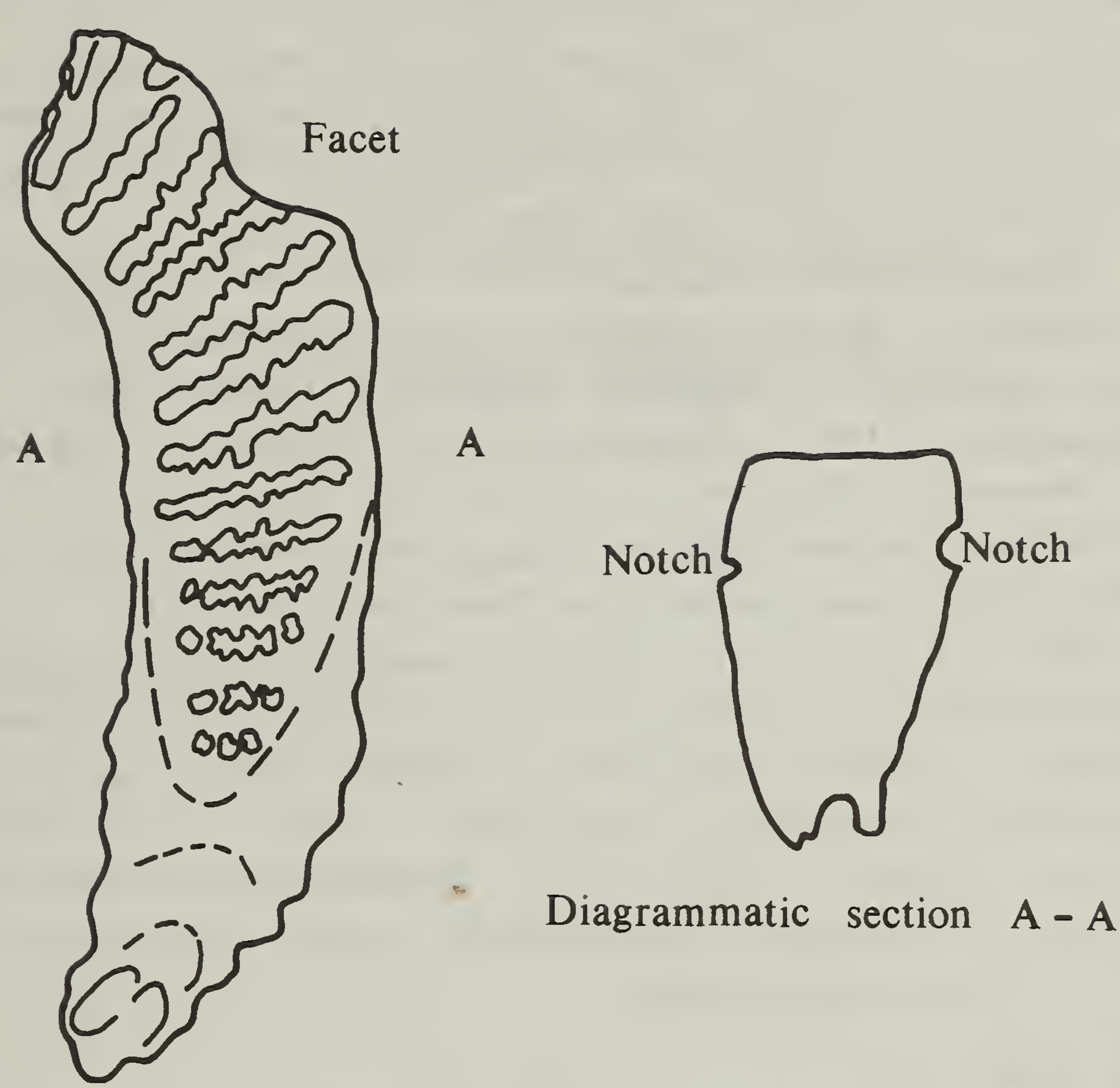

Fig. 2. Occlusal view of P. antiquus tooth from Wortwell, showing abnormalities

Some bones collected at this time are in Norwich Castle Museum (no. 239.957) and were recorded as horse, ox, red deer, reindeer, fallow deer and rhinoceros. The record of fallow deer and a tooth described as brown bear in the possession of the owner were then incorrectly identified, they are in fact reindeer and red deer respectively. Several hundred bones were retrieved from the site and although badly weathered in many cases, after conservation the following species have been identified -

Palaeoloxodon antiquus (Falc. and Caut.), *Hippopotamus amphibius* L., *Cervus elaphus* L., *Bos primigenius* Boj., *Equus caballus* L., *Rangifer tarandus* L., *Mammuthus primigenius* (Blum.), *Rhinoceros* sp., *Bison* sp., *Bos* sp.

Because of the poor condition of the bones a distinction between *Bos* and *Bison* metapodials, with estimation of age and sex has been unsuccessful.

This is obviously a mixed fauna, but the presence of hippopotamus can be taken as a good indicator of Ipswichian deposits, at about 13m depth. Clarke's notes suggest a Mesolithic date from the upper peat layer at 5.8m depth and record *Bos* from this level. Presumably the mammoth, reindeer, bison and horse occurred in the intervening gravel of Weichselian age.

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LOWER PLEISTOCENE MOLLUSCAN ASSEMBLAGES AND POLLEN FROM THE CRAG OF ALDEBY (NORFOLK) AND EASTON BAVENTS (SUFFOLK)

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Summary

Molluscan assemblages from the Crag at Aldeby and Easton Bavents are described and a pollen diagram from Aldeby is presented. This shows a Baventian pollen spectrum enabling correlation with the deposits at Ludham and Easton Bavents to be made. It is suggested that the Aldeby shelly Crag is Antian in age. Palaeoecological interpretations from the three sites are compared. The following marine facies in the Antian - early Baventian are deduced:

1. A littoral facies of the early Antian, with deposits at Easton Bavents.
2. An inner-sublittoral facies of the Antian at Aldeby, Easton Bavents and Ludham. The sea-bed at Aldeby was varied with many habitats for Mollusca. Around Easton Bavents it was more uniform, coarse with muddy interstitial material. At Ludham it was varied, with freshwater influence.
3. An early Baventian marine phase when the water was apparently deeper, and at Easton Bavents warmer as well, than in the Antian. The vegetational evidence from intercalated pollen analyses, however, suggests the climate was becoming colder. This problem awaits solution.

Introduction

Modern studies of the early Pleistocene sequence in East Anglia are summarised by West (1968, pp. 241-246).

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He recognises Stages named Ludhamian, Thurnian, Antian, Baventian, Pastonian, Beestonian and Cromerian. Mollusca have been described by Norton (1967) from the first four named Stages at Ludham (below surface) and from the Baventian at Sidestrand (outcropping). A summary of the sequence of molluscan assemblages in all these Stages and at many other sites is given by Norton (1970). This paper describes the molluscan assemblages at two outcrops, Aldeby and Easton Bavents. The shelly deposits at both belong to the "Norwich Horizon" (Harmer 1902).

Aldeby

Aldeby Brickyard (grid reference TM 431930) was worked during the middle 19th century. The early Pleistocene succession is described by Rose (1868), Prestwich (1871), Woodward (1881) and Reid (1890). Lists of Mollusca are given by Prestwich and Woodward, from records by Crowfoot and Dowson.

In March 1966 a section was reopened in the western embayment of the old pit, where a large oak tree stands below the face. The Paramoudra Club, (now the Geological Society of Norfolk) and the Ipswich Geological Group dug it. The succession was as follows:

0 - 60 cm	Soil
60 - 343 cm	Sands (current bedded at 148 - 162 cms) with gravelly layers at 100 - 120 cms, 130 - 148 cms and 182 - 343 cms
343 - 403 cm	Medium-fine yellow sand with brownish clay layers (no pollen) at 409 - 410 cms, 418 - 419 cms, 423 - 428 cms
441 - 503 cm	Yellow-gray silty clay (no pollen) with pockets of sand
503 - 551 cm	Grey laminated silty clay (no pollen) alternating with orange-yellow medium sand. A line of pebbles, 1 - 2 cms across, at 543 cms

551 - 638 cm	Orange loamy sand with grey laminated silty clay (no pollen) at 573 - 578 cms, silty grey clay (no pollen) at 612 - 615 cms, layers of grey laminated silty clay (no pollen) at 629 - 638 cms
638 - 683 cm	Laminated silty clay alternating with yellow-brown silty sand. Pollen from 660 cms downwards. At 663 cms a thin layer of grey-yellow weathered clay with a cracked surface (possible interruption of deposition). Below 665 cms, bluer with ferruginous partings
683 - 798 cm	Laminated sticky blue-grey polleniferous clay with partings of pure milky quartz sand to 786 cms; ferruginous sand partings below
833 - 868 cm	Fine medium-brown sand with a few shells. An undulating line of shells at 858 cms. Greyer below 843 cms
868 - 875 cm	Grey medium-fine sand densely packed with shells, many with the valves together
875 - 885 cm	Brown medium sand with no shells, to base of excavation at 885 cms.

Woodward (1881) and Reid (1890) described sections to the east (the 'central part of the pit') and west of this one. The 1966 profile interpolates satisfactorily. It is suggested that the Shell Bed be considered as Antian. The clay above is Baventian, as shown below, and no obvious unconformity was observed in the section. The molluscan assemblage, though less diverse, is similar to that of Shell Beds 3 and 4 at Easton Bavents, which are demonstrably Antian.

Pollen (R.B.B.)

Pollen samples were taken in all argillaceous layers but no significant pollen totals were recorded above 650 cms.

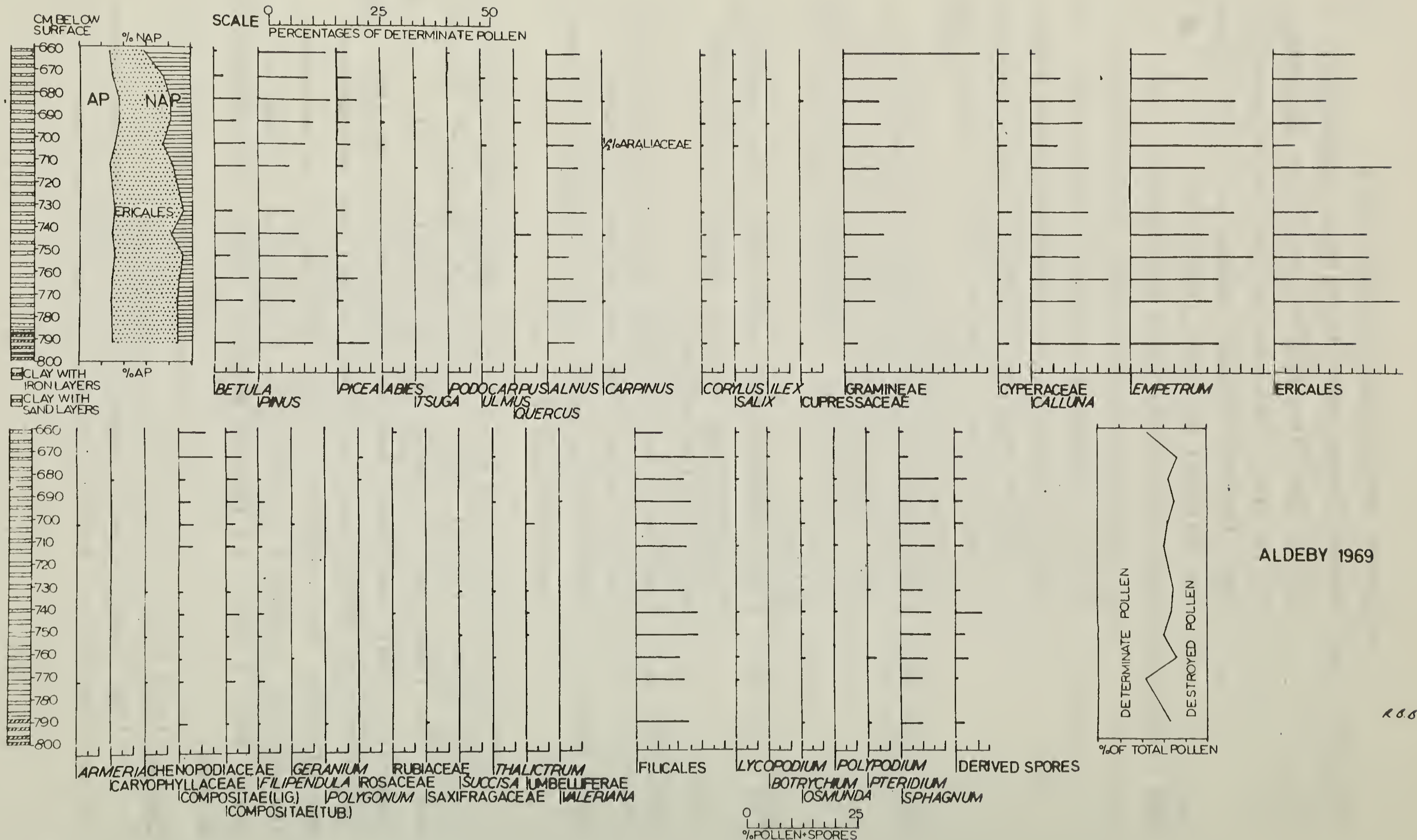

Fig. 1. Aldeby: Pollen diagram

Below this the pollen diagram shows the following features. The Arboreal Pollen (A.P.) percentage is never more than 40. There are high percentages of Ericales pollen, from 60% at the base of the diagram to 25% at the top. Of the trees represented, only the pollen of Betula, Pinus, Picea and Alnus reaches over 5%, the subsidiary genera being Abies, Tsuga, Podocarpus - type, Ulmus, Quercus and Carpinus. As ready mentioned, the Ericales dominate the Non-Arboreal Pollen (N.A.P.) with subsidiary amounts of Gramineae, Cyperaceae and Compositae. Sphagnum and Filicales are the chief non-flowering plants present throughout.

The general absence of thermophilous trees, coupled with the dominance of Ericales, suggests a correlation with one of the cold phases of the early Pleistocene proposed by West (1961) from the diagram of the Royal Society Borehole at Ludham, Norfolk. The two cold phases there are the Thurnian, L2 and the Baventian, L4. It is proposed that the Aldeby clay be correlated with the Baventian, subzone L4b, since Betula, Pinus and Alnus are more or less equally frequent and the rest of the diagram compares very closely with that from Ludham and also from Easton Bavents (Funnell and West, 1962).

Mollusca (P.E.P.N.)

The shells were examined using the methods described by Norton (1967). The results are shown in Table 1.

Listing the species so as to bring together those which are extinct since the early Pleistocene, or not extinct and having a similar present-day habitat, we obtain Figure 2.

The molluscan assemblages are characterised by Cyprina islandica, Spisula elliptica, Donax vittatus, Lepton nitidum, Mysella bidentata, Hiatella arctica and Cochlodesma praetenue. During deposition there has been much abrasion of the shells. Eighty per cent of them at 868 - 875 cms, 57% at 858 - 868 cms and 69% at 833 - 858

Table 1. Aldeby Mollusca

(Figures are to nearest 1%. 0 = less than ½%.
f = fragments only.
Dash denotes absence.)

		A 868 cms to 875 cms	B 858 cms to 868 cms	C 833 cms to 858 cms
1	Gastropods (indet.)	2	1	0
2	Gibbula sp.	0	-	-
3	Littorina littorea	0	-	-
4	L. cf. saxatilis	0	-	-
5	Clathrus clathratulus minutus	-	f	f
6	Calyptraea chinensis	0	0	-
7	Natica sp.	3	0	5
8	Nucella sp.	-	0	-
9	N. lapillus cf. lapillus	f	-	-
10	N. lapillus cf. vulgaris	-	-	0
11	N. cf tetragona	-	0	-
12	Lora trevelyana	-	-	f
13	L. cf. trevelyana	0	-	-
14	Retusa sp.	-	0	-
15	Actaeon sp.	-	f	0
16	cf. Actaeon	-	0	-
17	Pyramidellid sp.	-	0	-
18	Chrysallida indistincta	-	0	-
19	Bivalves (indet.)	12	12	10
20	Nucula sp.	0	0	0
21	N. cobboldiae	f	-	f
22	Yoldia sp.	1	3	2
23	Y. myalis	-	-	0
24	Y. cf. semistriata	0	-	-
25	Modiolus sp.	2	-	-
26	cf. Modiolus	-	6	-
27	Mytilus edulis	0	-	1
28	Pinna rudis	-	f	-
29	Anomia sp.	f	-	0
30	Astarte sp.	-	0	-
31	A. cf. incerta	-	0	-
32	A. cf. montagui	0	-	0
33	cf. Cyprina	1	-	-
34	Cyprina sp.	-	10	
35	C. islandica	7	1	
36	Lucinoma borealis	0	0	0
37	L. cf. borealis	-	f	-
38	Lepton nitidum	6	-	-
39	L. cf. nitidum	-	-	5

Table 1 continued		A 868 cms to 875 cms	B 858 cms to 868 cms	C 833 cms to 858 cms
40	*Mysella bidentata*	1	2	-
41	*M.* cf. *bidentata*	-	-	1
42	*M. ferruginosa*	-	1	-
43	*Lasaea intermedia*	-	9	-
44	*Cardium* sp.	0	f	-
45	*C. edule*	f	-	f
46	*Parvidardium scabrum*	-	1	0
47	*P.* cf. *scabrum*	0	-	-
48	*Serripes groenlandicus*	0	-	-
49	*Spisula* sp.	35	21	45
50	S. elliptica	1	-	2
51	*S.* cf. *elliptica*	-	12	-
52	*Abra* sp.	0	0	1
53	*Donax* sp.	2	-	-
54	*D. vittatus*	0	4	3
55	*Macoma* sp.	4	1	3
56	*M. calcarea*	0	-	-
57	*M. obliqua*	4	0	0
58	cf. *Hiatella*	1	-	-
59	*Hiatella* sp.	-	-	1
60	*H. arctica*	1	11	3
61	*Sphenia binghami*	-	0	-
62	*Corbula gibba*	0	0	1
63	*Mya* sp.	14	0	1
64	*M. arenaria*	0	-	-
65	*M.* cf. *truncata*	-	-	1
66	*Cochlodesma praetenue*	1	2	1

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cms are too worn for accurate determination. Presumably this was caused by rough seas or reworking of the shells. Turning to those which can be determined accurately, we find a small percentage belong to species which have become extinct since the Aldeby deposition time (1% at 868 - 875 cms - called hereafter sample A; 10% at 858 - 868 cms - sample B; 1% at 833 - 858 cms - sample C). There is modern ecological data on the remainder. Species of infralittoral and littoral affinity are very poorly

ALDEBY BRICKYARD, 1966. MOLLUSCA : ECOLOGICAL GROUPS. Frequencies are to nearest 1%. 0 = less than ½%. F = fragments only.				SAMPLES, with depth below surface: A 868 cm to 875 cm	B 858 cm to 868 cm	C 833 cm to 858 cm
LITTORAL	INFAUNA		Cardium edule (45)	F		F
LITTORAL	EPIFAUNA		Littorina cf saxatilis (4) L. littorea (3) Nucella lapillus (9) Mytilus edulis (27)	0		1
INFRA-LITTORAL	IN-FAUNA		Mya arenaria (64)	0		
INFRA-LITTORAL	IN-FAUNA		Cochlodesma praetenue (66)	1	2	2
INFRA-LITTORAL	EPIFAUNA		Calyptraea chinensis (6)	0	0	
SUBLITTORAL	INFAUNA	WIDE TOLERANCE	Parvicardium scabrum (46)	0	1	0
SUBLITTORAL	INFAUNA	COARSE MATERIAL WITH MUD	Spisula cf elliptica (50, 51) Macoma calcarea (56) Corbula gibba (62)	1	13	3
SUBLITTORAL	INFAUNA	CLEAN FINE OR SANDY OR MUDDY COARSE	Astarte montagui (32)	0		0
SUBLITTORAL	INFAUNA	MUDDY FINE OR COARSE	Lucinoma borealis (36)	0	0	0
SUBLITTORAL	INFAUNA	FIRM SAND OR MUDDY SAND	Cyprina islandica (35)	7	1	10
SUBLITTORAL	INFAUNA	SAND, SANDY MUD OR CLAY	Mya cf truncata (65)			1
SUBLITTORAL	INFAUNA	CLAY, ARCTIC DISTRIBUTION	Serripes groenlandicus (48)	0		
SUBLITTORAL	INFAUNA	CLEAN FIRM SAND	Donax vittatus (54)	0	4	3
SUBLITTORAL	EPIFAUNA	STONES OR SHELLS	Hiatella arctica (60) Sphenia binghami (61)	1	11	3
SUBLITTORAL	EPIFAUNA	SHELLY MUD AND FINE SAND	Chrysallida indistincta (18)		0	
SUBLITTORAL	EPIFAUNA	MUDDY SAND OR CLAY	Lora trevelyana (12, 13)	0		F
SUBLITTORAL	EPIFAUNA	COM-MENSAL: HOST IN MUDDY SAND OR SHELLY GRAVEL	Lepton nitidum (38, 39) Mysella bidentata (40, 41)	7	2	6
SUBLITTORAL	EPIFAUNA	COM-MENSAL: HOST IN CLEAN, COARSE MAT'L	Montacuta ferruginosa (42)		1	
SUMMARIES	Numerals after species & here refer to Table 1	5, 10, 11, 21, 23, 24, 28, 31, 43, 57.	EXTINCT	1	10	1
SUMMARIES		1, 2, 7, 8, 14, 16, 17, 19, 20, 22, 25, 26, 29, 30, 33, 34, 44, 49, 52, 53, 55, 58, 59, 63.	ABRADED	80	57	69
SUMMARIES		INFORMATIVES	TOTAL INFORMATIVE	19	33	30
SUMMARIES		INFORMATIVES	LITTORAL & INFRALITTORAL	2	2	4
SUMMARIES		INFORMATIVES	SUBTIDAL EPIFAUNA	8	14	9
SUMMARIES		INFORMATIVES	SUBTIDAL INFAUNA	9	17	17

Fig. 2. Aldeby: Mollusca, showing ecological groups

represented (2% - 4%). Sublittoral forms are prevalent (sample A, 17% in the 19% of fully determinable shells; sample B, 31% in 33%; sample C, 17% in 26%). Three types are particularly frequent. Spisula elliptica, Corbula gibba and Macoma calcarea are the most frequent and at the present day are found in coarse bottom material with interstitial mud. Cyprina islandica, the next, inhabits firm or muddy sand. Donax vittatus, the other, lives in clean firm sand. It is much less frequent in the samples. In very small numbers occur types which today are associated with shell gravel on the one hand (Parvicardium scabrum) and with clay or mud on the other (Serripes groenlandicus, Mya truncata).

Turning to what is interpreted as the sublittoral epifaunal element of the death assemblages, one of the most frequent species is Hiatella arctica (1% in 8%, sample A; 11% in 14%, B; 3% in 9%, C). H. arctica inhabits crevices and laminarian holdfasts, etc. on a clean stony or shelly bottom. Two other frequent epifaunal forms are Lepton nitidum and Mysella bidentata which are commensals. Their hosts live in muddy and sandy gravel.

On the basis of modern habitat preferences therefore, the life-associations from which these degraded death-assemblages came are interpreted as having lived in shallow sublittoral conditions in a sandy-bottomed sea with mud and some coarser material in patches. The evidence is that a variety of habitats were found in the area, from which the various infaunal and epifaunal types (already mentioned) were derived. A depth of 10 - 15 m below mean low tide mark or not more than 20 m is suggested as that at which they lived and were deposited. All the characterising species would flourish in this range. If the sea had been deeper at the place of deposition the assemblages would have been less abraded and if it had been shallower there would have been more littoral forms.

However, mechanical analyses (Table 2) show that the Aldeby sediments are very well sorted.

Table 2 Mechanical analyses of the Aldeby Shell Bed

	% by weight in Sample		
	A 868-875 cms	B 858-868 cms	C 833-858 cms
Fine gravel to 2000 µ	6.3	0.7	0.3
Coarse sand to 600 µ	5.9	1.7	1.2
Medium sand to 210 µ	32.1	33.9	44.8
Fine sand to 60 µ	44.8	58.2	54.2
less than 60 µ	10.9	5.0	0.4

Mr. P. G. Cambridge made these analyses. Subsamples of about 100 gms were obtained using a sample splitter. They were shaken for 10 minutes on an Endecott machine using sieves with BSS meshes 8, 14, 16, 25, 36, 72, 120, 200.

Except in Sample A the principal component is in the medium and fine sand grades, with little coarse material or fines. It is supposed that the whole shell bed has been formed as a concentrate by turbulence or migration of channels on the sea-bed, but that the part from 868 - 875 cms (sample A) approaches more closely the original conditions of the life-environment. Shells were found here with the valves together.

Most of the species are typical of the Boreal zoogeographic region at present. Serripes groenlandicus (one valve in sample A) is now an Arctic form. Macoma calcarea (one individual in sample A) is now only relict in the Boreal region. In the same sample is Calyptraea chinensis, now a Lusitanic form. This 'overlapping' has been noted in the Ludham Borehole assemblages also, at all levels (Norton 1967).

Easton Bavents

The succession is described, with a summary of literature and a description of the vegetational and

foraminiferal sequence, by Funnell and West (1962). They also summarise previous work on the Mollusca, especially by Larwood and Martin (1953) and on heavy minerals (Solomon 1935 and appendix to Funnell and West op cit.).

A series of samples was taken by Norton and Dr. R. G. West in 1967. The lithology was not precisely the same as described in 1962, the cliff having gone back several metres.

above 0 cm Blue-grey laminated clay (Baventian clay) (= 4.42 m O.D., levelled)

0 - 30 cm	Rusty clay with sand partings
30 - 45 cm	Stony sand
45 - 78 cm	Shell Bed 1 (sampled)
78 - 124 cm	Red loamy sand, fewer shells
124 - 138 cm	Shell Bed 2, more comminuted (sampled)
138 - 162 cm	Red loamy sand and shells
162 - 175 cm	Shell Bed 3 (sampled)
175 - 230 cm	Red loamy sand and shells
230 - 247 cm	Shell Bed 4 (sampled)
247 - 265 cm	Pale sand, grey clay laminae at 260 cms and (thinner) below
265 - 270 cm	Redder sand
270 - 271 cm	Red-grey clay lamina
271 - 280 cm	Shell Bed 5 (sampled)
280 - 290 cm	Red-grey sand laminated with grey clay at 289 cms.

The following correlations are proposed on comparing this section (seen 1967) and Funnell and West's section (seen 1961).

0 cms (1967 section) = 175 cms (1961 section)

Shell Beds 1 and 2 (1967) are Baventian.

(L4b pollen was at 175 - 210 cms (1961), above the level of Shell Bed 1 (1967). Zone E.B. II Foraminifera were at 265 cms (1961), below the level of Shell Bed 1 (1967) and

at 300 cms (1961), at the level of Shell Bed 2 (1967). L4b pollen was also at 300 cms.)

Shell Beds 3, 4 and 5 (1967) are Antian. (They fall between the boundaries of Pollen Zone L3 on West's diagram from the 1961 section, though the actual Antian pollen occurred only at 388 - 390 cms then - below the level of Shell Bed 3 (1967) but above 4 and 5.)

Mollusca (P.E.P.N.)

The Mollusca which occurred in the Shell Bed samples are given in Table 3 and arranged for interpretation purposes in Figure 3.

Table 3. Easton Bavents 'B' Mollusca

(Frequencies are to nearest 1%. 0 = less than ½%
f = fragments only
Dash denotes absence.)

	Shell Bed 1	2	3	4	5
Depth	45 cm to 78 cm	124 cm to 138 cm	162 cm to 175 cm	230 cm to 247 cm	271 cm to 280 cm
1 Chiton plates	-	f	-	-	-
2 Gastropod (indet.)	3	3	1	6	8
3 *Gibbula* sp.	1	0	-	-	-
4 *Littorina* sp.	4	5	-	-	-
5 *L. littorea*	-	-	-	2	7
6 *L. saxatilis*	2	3	1	-	12
7 *Clathrus* sp.	-	f	-	-	-
8 *Calyptraea chinensis*	0	2	3	-	-
9 *Natica* sp.	-	-	1	-	-
10 *Nucella lapillus*	1	f	2	-	f
11 *Buccinum undatum*	-	-	-	f	-
12 *Retusa* sp.	0	-	-	-	3
13 Bivalve (indet.)	5	8	9	1	6
14 *Nucula* sp.	f	-	2	-	-
15 *N. cobboldiae*	-	0	0	-	-
16 *Yoldia* sp.	2	3	5	7	0
17 *Y.* cf. *myalis*	-	-	1	1	-
18 Mytilus sp.	1	-	1	-	1
19 *M. edulis*	-	1	-	1	2
20 *Chlamys opercularis*	-	-	-	f	-

Table 3 continued

	Shell Bed 1	2	3	4	5
	Depth 45 cm to 78 cm	124 cm to 138 cm	162 cm to 175 cm	230 cm to 247 cm	271 cm to 280 cm
21 _C_. _tigerinus_	0	-	-	-	-
22 _Anomia_ sp.	-	0	-	f	-
23 _Astarte_ sp.	7	-	-	-	-
24 _A_. _montagui_	-	2	-	-	-
25 _A_. cf. _montagui_	-	2	1	-	-
26 _A_. cf. _montagui_ or _incerta_	-	1	-	-	-
27 _Cyprina islandica_	0	1	2	2	-
28 _Diplodonta_ or _Lucinoma_ sp.	-	-	-	1	0
29 _Leptonid_	-	1	-	-	5
30 _Lepton_ cf. _deltoideum_	-	-	-	-	0
31 _Mysella_ sp.	-	-	-	-	1
32 _Cardium_ sp.	5	4	1	4	15
33 _C_. _edule_	-	0	-	1	2
34 _C_. cf. _edule_	-	-	-	-	5
35 Veneracean	-	0	-	-	-
36 _Venus_ sp.	-	-	-	1	-
37 _V_. _ovata_	0	1	0	-	0
38 _Venerupis_ sp.	0	-	-	-	0
39 _Spisula_ sp.	7	11	-	3	9
40 _S_. cf. _elliptica_	-	0	-	-	-
41 _S_. cf. _subtruncata_	-	-	2	-	1
42 _Abra_ sp.	0	1	-	-	2
43 _Scrobicularia_ cf. _plana_	-	-	1	-	-
44 Tellinid	-	-	-	4	15
45 _Macoma_ sp.	10	4	24	18	-
46 _M_. _calcarea_	0	-	12	10	-
47 _M_. _obliqua_	1	1	18	23	1
48 _M_. _praetenuis_	-	-	-	5	-
49 _M_. cf. _praetenuis_	-	-	1	-	-
50 _Hiatella arctica_	-	2	-	-	-
51 _Corbula gibba_	47	40	11	4	1
52 _Sphenia binghami_	-	0	-	-	-
53 _Mya_ sp.	1	2	0	4	-
54 _M_. _arenaria_	2	1	-	-	-
55 _Cochlodesma praetenue_	1	-	0	-	-

In Shell Bed 1, 44% of shells were not possible to determine accurately; in Shell Bed 2, 44%; Shell Bed 3, 43%; Shell Bed 4, 53%; Shell Bed 5, 68%. On the basis of the remaining shells, which could be accurately determined, the following paleoecological interpretation is offered. The sequence is considered in three parts.

<u>Shell Bed 5, 271 - 280 cms</u>

Characterising species are *Littorina saxatilis*, *L. littorea*, *Cardium edule*, *Mytilus edulis*, *Corbula gibba*. Intertidal forms are the commonest, sublittoral ones are almost absent. *Littorina saxatilis* occurs on rocky surfaces and cannot be *in situ* here. Shell Bed 5 is interpreted as a littoral or infralittoral deposit. If more shells had been determinable, a larger sublittoral component might have been counted, for instance the 9% of *Spisula* sp., 5% of Leptonidae and 2% of *Abra*. Note however there are also 15% of *Cardium* sp, 8% Gastropoda and 15% Tellinidae, about which no such suggestion is valid. Zoogeographically the characteristic species are at present Boreal forms, common in northwest European waters.

<u>Shell Beds 3 and 4, and associated deposits, 162 - 247 cms</u>

Characterised by *Macoma obliqua*, *M. calcarea*, *Corbula gibba*, *Cyprina islandica*, *Spisula subtruncata* and *Littorina littorea*. Here, sublittoral forms outnumber littoral ones by 3 or 4 to 1. This is a contrast with Shell Bed 5 (discussed below). Among the sublittoral forms the only frequent ones are infaunal types, *Corbula gibba* and *Macoma calcarea*. These live in coarse bottom material with interstitial mud. This is not the type of deposit in which the remains occurred.

EASTON BAVENTS 'B', 1967

MOLLUSCA : ECOLOGICAL GROUPS

Frequencies are given to nearest 1%.
0 = less than ½%. F = fragments only .

				SHELL BEDS, with depth below Baventian Clay base .				
				1 45 cm to 78 cm	2 124 cm to 138 cm	3 162 cm to 175 cm	4 230cm to 247 cm	5 271 cm to 280 cm
TIDAL ZONE	INFAUNA		Cardium edule(33, 34) Scrobicularia cf plana (43)		0	1	1	7
TIDAL ZONE	EPIFAUNA		Littorina saxatilis (6) Littorina littorea(5) Nucella lapillus (10) Mytilus edulis (19)	3	4	3	3	21
INFRALITTORAL	IN-FAUNA	SANDY GRAVEL, SAND OR MUD	Mya arenaria (54)	2	1			
INFRALITTORAL	IN-FAUNA	SAND OR MUDDY GRAVEL	Cochlodesma praetenue (55)	1		0		
INFRALITTORAL	EPI-FAUNA	ON STONES ETC: SILTY PLACES	Calyptraea chinensis (8)	0	2	3		
SUBLITTORAL	INFAUNA	WIDE TOLERANCE	Venus ovata (37)	0	1	0		0
SUBLITTORAL	INFAUNA	COARSE MATERIAL WITH MUD	Spisula cf elliptica (40) Macoma calcarea (46) Corbula gibba (51)	48	40	23	15	1
SUBLITTORAL	INFAUNA	CLEAN FINE OR SANDY OR MUDDY COARSE	Astarte montagui (24,25)		5	1		
SUBLITTORAL	INFAUNA	SAND, SILTY SAND OR MUDDY SAND	Spisula subtruncata (41)			2		1
SUBLITTORAL	INFAUNA	FIRM SAND OR MUDDY SAND	Cyprina islandica (27)		1	2	2	
SUBLITTORAL	EPIFAUNA	STONES OR SHELLS	Sphenia binghami (52) Hiatella arctica (50)		2			
SUBLITTORAL	EPIFAUNA	FIRM BOTTOM OF ROCK OR MUD	Buccinum undatum (11)				F	
SUBLITTORAL	EPIFAUNA	SHELL GRAVEL, SANDY GRAVEL, OR SANDY MUD	Chlamys opercularis (20)				F	
SUBLITTORAL	EPIFAUNA	STONES, GRAVEL, COARSE SANDY MUD	Chlamys tigerinus (21)	0				
SUMMARIES	Numerals after species and in this column refer to Table 3.	15, 17, 30, 47, 48	EXTINCT	1	1	21	28	1
SUMMARIES		1, 2, 3, 4, 7, 9, 12, 13, 16, 18, 22, 23, 26, 28, 29, 31, 32, 35, 36, 38, 39, 42 44, 45, 53.	ABRADED	44	44	43	53	68
SUMMARIES		INFORMATIVES	TOTAL	55	55	36	19	31
SUMMARIES		INFORMATIVES	LITTORAL & INFRALITTORAL	6	6	7	4	28
SUMMARIES		INFORMATIVES	SUBLITTORAL	49	49	29	15	3

Fig. 3. Easton Bavents 'B': Mollusca, showing ecological groups

Table 4. Mechanical analyses of the Easton Bavents Sediments

	Shell Bed 1	2	3	4	5
Fine gravel to 2000 µ	11.3	26.0	28.9	10.9	5.8
Coarse sand to 600 µ	21.5	39.3	26.1	10.6	7.8
Medium sand to 210 µ	52.8	17.7	27.9	21.8	63.4
Fine sand to 60 µ	13.9	15.3	16.8	52.1	22.3
finer than 60 µ	1.6	1.9	0.3	5.4	0.7

(These were made by Mr. P. G. Cambridge by the same methods as were used for the Aldeby Analyses).

The mechanical analyses of the sediments (Table 4) show that Shell Bed 4 has a preponderance of fine and medium sand, Shell Bed 3 being well dispersed but coarser. Neither bed contained much silt or clay. This with the lithology of the deposit and the high percentage of abraded shells, suggests that the death assemblages are allochthonous.

The species, as in Shell Bed 5, are mainly distributed in Boreal waters today. *Macoma calcarea* has a Subarctic distribution, with relict populations in the Danish Belt Seas. *Macoma obliqua*, now extinct, is very frequent in these shell beds.

Shell Beds 1 and 2 and associated deposits, 45 - 138 cms

Characterising species are *Corbula gibba*, *Littorina saxatilis*, *Astarte montagui*, *Mya arenaria*, *Hiatella arctica*. The sublittoral forms again outnumber the littoral ones here, by about 8 to 1. *Corbula gibba* forms about 40% of the assemblage. Its ecology has been described by Yonge (1946). It is specialised for life in gravel and small stones with thick muddy sand. Table 4 shows much coarse material in the sediment but a lack of silt and clay. *Macoma calcarea*, common in Shell Beds 3 and 4, is insignificant here (further discussion below). It is

considered that the Mollusca generally indicate temperatures similar to those of modern Boreal seas, and that they are deposited in sediments other than those in which they lived.

General Discussion. It has been noted that the Mollusca, in life, would have inhabited sediments unlike those in the Shell Beds. The present Shell Beds were probably concentrated by migration of channels on the sea-bed and by turbulent conditions. It is not easy to conclude the depth at which they formed. The ratio of sublittoral forms to littoral ones changes from one shell in nine (Shell Bed 5) through 3 : 1 (Bed 4) and 4 : 1 (Bed 3) to 8 : 1 (Beds 1 and 2). Shell Bed 5 is considered to be a littoral or infralittoral deposit, formed less than 5 m below mean low tide mark. The infrequency of littoral forms in the other shell beds suggest that they formed in more than 5 m of water, while the frequency of worn shells suggests formation in less than 15 m. It is inferred (from the ratios above) that the water became deeper as deposition continued, and less turbulent so that in Shell Beds 1 and 2 markedly fewer shells are abraded (as mentioned above). These species in the Shell Beds, which are interpreted as sublittoral on the basis of their modern ecology, all would flourish today between 5 m and 15 m depth.

Macoma calcarea and *Corbula gibba* occur in Shell Bed 3 where they are very frequent. *Corbula gibba* alone occurs in Shell Bed 2 (with a higher frequency, equal to its own in Shell Bed 3 plus that of *M. calcarea* there). It is possible that ecological changes caused this 'replacement', for example an alteration in the sea-bed type or the water temperatures. However, both species flourish in coarse material with interstitial mud. The habitat of *Corbula gibba* has already been referred to,

that of *Macoma calcarea* is mud, with clay, stones, shells and gravel (Odhner 1915). On the other hand, their temperature tolerances are different. *M. calcarea*, according to Sorgenfrei (1958, p.391) has its maximum occurrence at an annual average of 7°C, *Corbula gibba* at 10 - 15°C. This suggests the water was warmer when the Shell Bed 2 molluscs were living than when those in Shell Bed 3 were living. However, there is no corresponding change in the Ludham Borehole Mollusca at the Antian-Baventian boundary (Norton 1967). Also, the pollen at these levels indicates increasing cold at both sites. Thus the change in the Easton Bavents Mollusca may be due to some alteration in the depositional conditions, not to ecological changes.

Marine Facies in the Antian and Early Baventian

No molluscan species or group of species can be used to infer synchroneity or non-synchroneity between the Shell Beds at Aldeby, Easton Bavents and Ludham (Zones L.M.5 and L.M.6). Certain resemblances emerge in the paleoecological interpretations based on these shell assemblages. One such resemblance (discussed below) exists between Shell Beds 3 and 4 at Easton Bavents and the Shell Bed at Aldeby. These Easton Bavents beds are Antian, on palynological grounds. It has therefore been proposed (above) that the Aldeby Shell Bed be considered Antian, though it lacks pollen, and zone L4a is missing at Aldeby, where the overlying clay is Baventian, L4b subzone. If this proposal is accepted, a preliminary discussion of distribution of marine facies during the Antian and early Baventian can be attempted. The interpretations from the molluscan assemblages are thought to have local, not general, significance.

Shell Bed 5 at Easton Bavents is interpreted as part of a local littoral marine facies of the early Antian. The Mollusca which remain unworn enough to determine are mainly littoral forms.

The Crag of Aldeby and the Easton Bavents Shell Beds 3 and 4 are considered to represent an inner-sublittoral marine facies of Antian age. At Aldeby, a diversity of habitats on the sea-bed is represented in the death assemblages. At Easton Bavents, less diverse molluscan assemblages occur. The commonest forms are bivalves specialised for life in coarse sea-beds with muddy interstitial material. At Ludham, an inner-sublittoral facies with proximity of estuarine conditions existed throughout the Antian (Norton 1967). Conditions there were less turbulent. Fewer abraded shells occur. Hydrobia ulvae is common and Planorbis leucostoma occurs.

Shell Beds 1 and 2 at Easton Bavents and Zone L.M.6 at Ludham are Baventian. There are lower percentages of littoral forms than in the Antian assemblages. Apparently the sea had become deeper at both sites. There is also an indication (possibly misleading) that it became warmer at Easton Bavents, but no such evidence at Ludham, as noted already. Vegetational evidence, however, indicates the climate was becoming colder and a glacio-eustatic fall of sealevel would be expected. No explanation can be offered for this apparent contradiction. Evidence should be sought that the Baventian molluscan assemblages were formed by reworking of Antian shell beds. This is not so far forthcoming. Instead of an increase in the percentage of abraded shells, there is a decrease at Easton Bavents. At Ludham, there is a decrease then an increase. For a solution of this problem, more sites must be studied.

We thank the Paramoudra Club and the Ipswich Geological Group for help digging at Aldeby, Mr. P. G. Cambridge for making the mechanical analyses, Dr. R. G. West for help in sampling at Easton Bavents and for discussions, and Mrs. S. Norton for assistance in levelling. The pollen analysis was carried out by Dr. R. B. Beck

whilst at the Sub-department of Quaternary Research, University of Cambridge. Colonel Freeland kindly sanctioned the excavation on his land at Aldeby.

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GEOLOGY AT GRESHAM'S SCHOOL

R. COLEMAN*

A feature of Technical colleges and Comprehensive schools is the wide range of courses offered at both 'O' and 'A' levels, with all sorts of rare combinations possible according to the students' choice. In smaller units, Grammar and Public schools, the range of subjects which is possible is generally more restricted, and, even after the past decade or so, in which Geology has received the "rubber stamp" of approval, it is still not widespread as an examination science or as a general curriculum subject. Gresham's School, whose foundation dates from the middle of the sixteenth century, has developed a strongly science-oriented reputation over the past seventy years - a reputation built on a large number of Oxbridge awards and places gained each year and notable distinctions of Old Boys. A traditional situation of this kind is not perhaps an ideal one into which one can make easy inroads with a "new" subject.

After a few tentative years when Geology was offered as a fourth 'A' level to the bright scientist or keen geologist, the subject for the past five years has been given the status of a normal 'A' level with a full two year course. It therefore takes its place in the four groups of subjects offered at 'A' level, each sixth-former selecting one subject from two to four of the groups according to his abilities and career needs. The boy is regarded as more important than the system - hence the wide choice of possible courses.

Boys studying Geology at Gresham's tend to fall into three major categories:

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(i) Boys intending to read Geology at University.

(ii) Boys keenly interested who feel a high grade (for University entry) possible, yet who will be reading some other subject as undergraduates.

(iii) Boys whose Mathematics is not strong enough to cope with Physics 'A' level with great success, and who wish nonetheless to gain three science 'A' levels, combining Geology with, usually, Biology and Chemistry. A large number of these will possibly have careers in agriculture, veterinary science, information science, technical writing, soil science, land surveying or museum work in mind, and find Geology acceptable as a means of getting onto a science-based degree course.

It is pointed out that the ideal base of 'A' levels for a degree course in Geology is more probably Chemistry, Physics and Mathematics than Geology itself, but the sixth former may be faced with the problem of entrance competition with, possibly, lower grades in some of these 'ideal' subjects; the weaker scientist may therefore turn to Geology. The total numbers involved generally remain between ten and fifteen in each year.

The organisation of the sixth form Geology course is naturally dictated by the needs of the examining boards' syllabus, the Oxford and Cambridge Board this year revising their requirements after a long unchanged run. The major changes incorporate some of the newer discoveries in Geology and attempt to cut down the amount of rote learning required, by placing more emphasis on the understanding of geological principles. A considerable amount of economic and engineering geology is included, and a new approach to the treatment of British Stratigraphy. It has long been apparent that it is unreasonable, some have said it more

strongly, for the beginner, to expect even a moderately detailed knowledge of the whole of British Stratigraphy at 'A' level. It is, at the same time however, difficult to examine the understanding of the subject of candidates who have a less detailed knowledge. To overcome these difficulties the new syllabus requires knowledge on two levels: one, a general outline of British Stratigraphy such as might be obtained from a '25 mile to the inch' map, and, two, a detailed knowledge of three specified stratigraphical systems which are changed annually. This part of the syllabus is regarded as the equivalent of "set books" in English Literature or special subjects in History.

Three papers are set:

Paper I consists of nine compulsory questions, each with some internal choice, covering the general principles of all major parts of the syllabus. This paper thus examines the candidate's general overall grasp of the subject.

Paper II is a traditional essay paper requiring a greater depth of knowledge with a question on the candidate's own fieldwork.

The third paper is a three hour practical with emphasis placed on the candidate's understanding of the geological significance of specimens rather than an ability to simply name, date and classify them. The interpretation of geological maps and photographs illustrating geological phenomena is included.

Two important lines of thought are used to develop this syllabus into a course. Firstly the subject should if possible proceed from the easy to the difficult over two years, and, secondly, those aspects of the subject which are observable and familiar today should precede those which are less familiar and perhaps completely theoretical. Nearly all sixth form Geologists will have recently completed an 'O' level Geography course and find

that the erosion processes leading on to sedimentation a field of study in which sixth form work habits can comfortably be acquired. Much later the more difficult topics of igneous and metamorphic petrology, and earth structures, with the complex theories that accompany them, can be more readily assimilated by the attuned mind than by the raw, recently graduated fifth former still accustomed, however regrettably, to the rote of 'O' level learning.

The course depends heavily for its stimulation on very good collections of minerals, rocks and fossils, which are available and with which the sixth former becomes familiar over two years. Individual sets are being prepared for each member of the course, though these may not have the uniformity one would wish to see, notably among the fossils, and replicas are prepared where required.

From the outset emphasis is placed on the essential fact that Geology is very much a fieldwork subject, and the true laboratory is the quarry or cliff-face. Our own courses are organised so that each candidate will have visited three quite different areas before examination. These areas - Northern Ireland, North Wales, Shropshire, the Lake District, Dorset and Western Scotland - offer a coverage of the major stratigraphical groups and the work given to the boys depends on their interests and attainments. It is hoped to achieve a recapitulation of material covered in the course to date, and to encourage original observations and the recording of evidence prior to further deduction. As a further incentive to members of the course, the building up of private collections is encouraged, and the success of this suggests that a number of family holidays have perhaps been turned into minor expeditions.

In addition to the main field courses, we are able to timetable the first year sixth form for a long session of geology in the summer term, enabling whole or half day visits to be made to some major East Anglian sites -

Hunstanton, nearby Weybourne, Wells and Trimingham, and beyond to the Charnwood Forest area and Corby.

Geology is not included in the curriculum prior to the sixth form, but a two hours' Hobbies session is organised for boys in the middle school who have an interest in the subject. This varies in form, including short field trips, fossil replica making, rock cutting and polishing, and films, the purpose being to encourage as many "geologists" as possible and give younger boys some indication of the spirit and purpose of the subject.

It does not seem likely that the subject will have opportunity for much expansion as an academic discipline at this level since most University seeking candidates for undergraduate Geology are not over keen that they should have Geology among their 'A' levels. Understandably, with techniques in the Earth Sciences becoming increasingly sophisticated and complex, it is more than ever necessary for candidates entering honours courses to have a thorough grounding in basic sciences like mathematics, physics and chemistry. The problem facing this schoolmaster is that of discouraging the would be professional geologist from his present geological studies and at the same time hoping to sustain his interest whilst two years of other scientific 'A' levels occupy his time and energies. If the subject is really one which many of the Universities would prefer to teach from the beginning its future in schools is bleak. This writer believes, however, that in many respects it has a considerable educational value and discipline which may outweigh the worth of several other sciences. Thirty-five years ago, A. E. Trueman wrote:

"Geology is pre-eminently the layman's science. In it more than in any other science there is opportunity for a beginner to make original observations, to weigh up evidence, to co-ordinate his facts, and in general to acquire a truly scientific outlook, whereas a layman can do no more in many sciences than accept ready made

conclusions, often explained by clever but dangerous analogies, without any prospect of understanding the steps by which they have been reached". And later, "the geologist acquires an eye for country and an understanding of nature not excelled by that of the artist or the poet".

Much has changed in Geology since 1937, but I believe Trueman's thesis remains sound, and, with a growing appreciation of his environment by the well educated man, and an increasing encouragement from further and higher educational circles, Geology will continue to expand at school level.

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BOOKS FOR STUDYING G.C.E. AND C.S.E. GEOLOGY

R. S. JOBY*

With the growing popularity of this subject as a school examination subject at all levels, there has been an increased demand and production of books suitable for those studying in schools and colleges. When starting new courses, teachers are faced with over one hundred possible titles, so in this article it is intended to examine some of those used with success by pupils and teachers, as a guide to those venturing into the field of Geology teaching.

All G.C.E. boards offer 'O' or 'AO' level papers, and all except Southern board offer 'A' level papers. Only a few C.S.E. boards have Mode 1 Geology examinations at present, but this should not deter potential teachers of the subject, as they can compose their own Mode 3 syllabus, which can be a very satisfying experience to those who find existing syllabuses frustrating.

With more than 1,000 schools teaching the subject, and more starting annually, there is a wide market for examination-oriented Geology books, and many of a different nature find their way into school libraries.

Few syllabuses have appended booklists, but by studying the syllabuses and publishers' lists, as well as the books themselves, one can work out the books available in print for the sections of the intended course. No single text comes anywhere near to covering any single syllabus adequately. The Cambridge 'AO' mapwork has been metricated, and no suitable introductory book in English appears to be available.

For C.S.E. and 'O' level syllabuses, the book giving the fullest coverage without loss of accuracy is 'A New Geology' by Michael Bradshaw, published by English Universities Press in 1968 and reprinted since. The

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diagrams are simple and easy to understand, and many of the photographs have not been used before in similar publications. Given that most pupils are new to the subject, and that the vocabulary will be unfamiliar to them, Bradshaw uses heavy type for every new technical term, which is then explained. There is no separate glossary, but judicious use of the index and text will enable a pupil to reach the same end result. An important feature is the effort to get the pupil to think three-dimensionally, and to consider the contents of each section with some searching tests and exercises at the end. Necessarily in the span of 250 pages, all topics have to be limited in their scope and number of examples, and this is especially so of map and practical work, covered in further volumes.

In conjunction with E. A. Jarman, Michael Bradshaw has produced two mapwork books in paper covers. The first deals with 1" Geological survey maps, describes and analyses them, while the second is a disposable map exercise book with useful step-by-step methodology. The books can be used separately, but as previously mentioned, are not metricated, while the Cambridge paper is. Also available for 'O' level mapwork, and likewise in Imperial units, is George Bennison's 'Introduction to Geological Strata and Maps', again with exercises to be done in the book. This is published by Edward Arnold and is now in its second edition. On the whole this lacks many of the qualities of the former books, and does not develop three-dimensional awareness so well.

More specialized books are needed for specific parts of the Geology syllabuses, and if money is in short supply, as so often now, then for Palaeontology and Petrology, two pocket-size handbooks published by Paul Hamlyn can be recommended. 'Rocks and Minerals' by Zim and Shaffer covers many more types than a general textbook, is very fully illustrated in colour, and is useful for the young field-

worker. Its companion 'Fossils' illustrates large numbers of the major fossil phyla, but is weak in their evolutionary development, except for the vertebrates. Both books can be carried in the pocket, but have very weak bindings, and disintegrate within two years.

Edward Arnold's Introduction to Geology series consists of four large paperbacks, 'Fossils' and 'British Stratigraphy' by F. Middlemiss, 'Rocks and Minerals' by A. Leigh, and 'Physical Geology' by L. Knowles. All are in black and white, have a large format and simplified explanations. Together they do not complete a syllabus, and are expensive when compared to a single good general text, yet do not add a great deal to it.

Physical Geology overlaps the main Geography syllabuses, and books can often be borrowed from colleagues, but if money is available, then Holmes' 'Elements of Physical Geology' in its latest edition is still unrivalled as an introduction to this part of the work. Thos. Nelson is the publisher.

For either C.S.E. or 'O' level, the teacher is unlikely to cover the course well with a book expenditure of less than £3 per head.

'A' level examinations in Geology go far deeper into the subject, and here the need to supplement a general textbook is much greater. The two most widely available course books are 'General Principles of Geology' by J. Kirkaldy, published by Hutchinson, and 'Beginning Geology' by H. Read and J. Watson. Both are well written and adequately illustrated, the former without photographs. Neither has the depth in any section to allow it to be used as a sole source, and consequently for each major sub-section of the subject, further books need to be bought. Physical Geology requires greater depth, and 'Physical Geology' by Holmes satisfies most needs, although price and size are large. 'Minerals, Rocks and Gemstones' by Börner, published by Oliver and Boyd, covers that part of the

syllabus, and is a good analytical compendium for the laboratory study of specimens as it is laid out diagnostically. 'Stratigraphy of the British Isles' by Bennison and Wright covers its topic fully, and has a paperback edition, which for the economic makes it preferable to Dorothy Rayner's similar volume. In Palaeontology, Middlemiss has an expanded volume similar in format to his 'O' level text. This is somewhat unevenly written and drawn. Probably older texts are as useful as any here, and Swinnerton's 'Fossils' in Collins New Naturalist series is as good as any.

Mapwork at 'A' level generally requires a knowledge of Geological Survey maps at 1" and/or $\frac{1}{4}$" scales. Bradshaw and Jarman's volume, which I have already mentioned, has been found the most satisfactory introduction to these maps, and of course, a geographically wide selection of map sets is needed - although single copies can be used with pupils on a rotating basis for map exercises.

Book costs for the 'A' level student are unlikely to be less than £10 per head, and could be much more to equip pupils really well for the searching questions set. In addition, unless the teacher is able to build a good collection and improvise much equipment, setting up costs can be high, but in a future article I hope to show how they can be mitigated.

Received July 1972

REPORT ON FIELD MEETINGS TO HUNSTANTON AND WEST RUNTON

P. G. CAMBRIDGE*

Hunstanton (25 June 1972)

The cliff section at Hunstanton scarcely needs description. The upper part of the Carstone is unfossiliferous but shows excellent current bedding, and although showing differences in cementation sometimes the jointing is so perfect that the beach resembles a flagged pavement. The striking Hunstanton Red Rock bears little resemblance to the Gault clay, of which it is the stratigraphical equivalent. It and the lower part of the Lower Chalk is extremely fossiliferous. Large branching structures are common at this level. They have been described as a sponge - *Spongia paradoxica* - but are more likely to be traces of a burrowing organism. Between the Red Rock and the Paradoxica Bed, is a thin seam rich in iron oxides, which weathers out leaving a series of cavities. A recent boring for water near Hunstanton penetrated this junction and gave a copious flow of bright red water.

The upper part of the section was examined from the beach by means of field glasses and the upper part of the chalk was seen to be disturbed by cryoturbation. Above this there is a very thin soil cover. An interesting feature was a saucer shaped depression full of soil, with a line of oyster shells, apparently *Ostrea edulis* L, toward the northern end of the section where the height of the cliff decreases. This was assumed to be an occupation level of some kind but the site was too high to be reached from the beach.

After traversing the full length of the cliff section, a disused gravel pit near Docking (NGR 765358) was visited. The general section appears to be a brown loamy till, mostly covered by scree, overlain by a highly calcareous gravel with coarse sand lenses. A very high proportion of the sand and gravel is composed of chalk, and in places it has been cemented to form concrete like masses. The harder pebbles

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are almost exclusively flint and a few fragments of iron-stone (Neocomian?). In addition to the flint pebbles there are also very large cylindrical flint masses penetrated by numerous cavities. The section is topped by several feet of shattered flints. Frost heaving, large solution pipes, current bedding and other interesting features were well represented.

Finally a stop was made alongside the road in the middle of an area of arable land just north of East Rudham (NGR 813300) to demonstrate the occurrence of numerous old pits in this part of Norfolk. Each field seen contained at least one such pit, situated well out in the middle of the field and now hidden by bushes and well-grown trees. In most cases these are old marl pits, tens of thousands of which have been opened in Norfolk. The marl - clay rich in chalk - was raised, often by means of a windlass from the deeper pits, for spreading on the fields, and the pits were strategically positioned to minimise the effort required to cart and spread the material. The cost of treating land in this way today is prohibitive and a similar effect is got by importing ground chalk into the area and spreading it mechanically.

West Runton (23 July 1972)

A previous visit to West Runton was described in Bulletin No. 21. On the present occasion the afternoon was spent examining cliff erosion and coast defences at Overstrand, and the Maastrichtian Chalk erratics and over-lying Quaternary deposits of Sidestrand. In the estuarine sands and silts above the Stone Bed and 'Weybourne Crag', thin flat pieces of cementstone occur which exhibit sun cracks, and mollusc borings, etc., and sometimes contain plant fragments and remains of shells. One of these pieces, which are abundant on the beach, was broken open and proved to contain a fine fossil example of the bryozoan *Flustra foliacea* L.

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GEOLOGICAL SOCIETY OF NORFOLK

WINTER MEETINGS

October 26th, 1972	PRESIDENTIAL ADDRESS Dr. R. G. West: "A state of confusion in Norfolk Pleistocene Stratigraphy" 7.30 Castle Museum
November 30th, 1972	Dr. F. J. Vine: "Geology of the Deep Ocean Floor" 7.30 Castle Museum
December 14th, 1972	A.G.M. and members slides 7.30 Castle Museum
January 25th, 1973	"Demonstration of techniques" 7.30 School of Environmental Sciences, U.E.A.
February 22nd, 1973	(To be confirmed)
March 29th, 1973	N. B. Peake, F.G.S.: "Maastrichtian and Danian in N. W. Europe" Arts Block I, U.E.A. 7.30
April 26th, 1973	"Members specimens" Arts Block I, U.E.A. 7.30

Members are reminded that subscriptions (£1) are due on 1st. October 1972 and that a bankers order is a convenient way of paying.

CONTENTS

The Geological Soceity of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may apply for election to the society. For further details write to the Secretary, Castle Museum, NORWICH, NOR 65B.

Copies of this Bulletin may be obtained 60p (post free) from the Society at the Castle Museum, NORWICH, NOR 65B; it is issued free to members.

Also available at 75p (post free) is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 23

CONTENTS INCLUDE:

Norfolk Pleistocene Stratigraphy
Nar Valley involutions
Base of the Carstone
Earth Science at the Open University
Secretary's Report for 1972

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EDITORIAL

With this edition we say goodbye to Brian McWilliams as our Secretary, happily he will still be with us in his new role as President of the Society. We welcome Dr. Christopher Aslin as our new Secretary, and also move our normal venue for lecture meetings from the Castle Museum to the University of East Anglia. Our thanks are due to Brian for his several years as Secretary, which culminated in excellent attendances at the Castle Museum for the autumn lectures. It is hoped that similar support will continue at our new location.

Dr. Richard West, our outgoing President, has written a summary of his Presidential Address which we are very happy to publish. This will provide a permanent record of a very stimulating lecture, which aroused many questions. The continuing series on Geology in education has this time a contribution from the Open University, where our contributor Dr. Wilson helped write the very interesting course. The Carstone is also investigated in two quite different ways by our other contributors, and for the first time we include a Secretary's Report for the year 1972.

Bulletin No. 24 will be issued in September 1973. Contributions should be sent to me as soon as possible, and no later than July 31, 1973.

Will contributors please note that manuscripts are acceptable in legible handwriting, although typewritten copy is preferred. In either case it would be a great help if details of capitalisation, underlining, punctuation, etc., in the headings and references (particularly) could conform strictly to those used in the Bulletin. Otherwise publication may be delayed.

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R.S.J.

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A STATE OF CONFUSION IN NORFOLK PLEISTOCENE STRATIGRAPHY

(a summary of the Presidential Address for 1972, delivered October 26, 1972)

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In the days of Clement Reid (1890) the Pleistocene started near the top of the Cromer Forest Bed Series, at the point where the oncoming of cold conditions was indicated by the presence of arctic plants (Arctic Freshwater Bed of Clement Reid). Nowadays the Pliocene/Pleistocene boundary is placed at the base of the Red Crag, so that the Pleistocene includes the thick series of marine sands and silts which comprise the Red, Norwich and Weybourne Crags. However, here I shall revert to Reid's definition, and discuss the stratigraphy of the glacial part of the Pleistocene, i.e. later than the Cromer Forest Bed Series. Suffice it to say that there is also a state of confusion in the Forest Bed and Crag part of the Pleistocene, with the sequence of climatic stages and their correlation with the continent not yet clearly defined.

The lower limit of the glacial Pleistocene can be taken for our purpose to be the top of the Cromer Forest Bed Series. The boundary between the Cromer Forest Bed Series and the earliest tills can be seen around the coast from Sheringham to Corton. The upper limit can be taken to be the glacial deposits and periglacial phenomena associated with the last (Devensian, i.e. Weichselian) glaciation. These glacial deposits include the Hunstanton Till of the north Norfolk coast, and the periglacial phenomena include the stripes and polygons of the Breckland and the frost mounds of central and west Norfolk. The form of these effects is closely related to the present topography, indicating that there has been little change since the last

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glaciation.

The problem which concerns us here is what happens between these limits. How many glacial advances were there, and what did each advance deposit?

There are two kinds of fixed points available in considering the sequence: till sheets which extend over a distance and can be ascribed to one glacial advance (such as the blue chalky boulder clay of central and east East Anglia) and interglacial deposits which show a regular and well-defined sequence of pollen assemblage zones (such as the Hoxnian interglacial vegetational sequence (West 1972)). The occurrence of a well-defined till sheet, underlain by or overlain by an interglacial deposit with a well-defined vegetational sequence, offers a very satisfactory fixed point in unravelling the glacial sequence.

Let us first take the fixed points in the sequence, and then see how problematical deposits have been fitted in by various authors.

Starting at the coast of Corton, we have the well-known tripartite sequence: Norwich Brickearth, Corton Sands, Lowestoft Till. Beneath the lower till occur peat deposits, with a fossil content indicating a correlation with the Cromerian at West Runton. The present evidence indicates that this tripartite sequence belongs to one cold stage (the Anglian), for there is no evidence that temperate conditions intervened at any time in the sequence.

Most students of the Pleistocene would agree that the Lowestoft Till extends inland to Hoxne, the type site for the Hoxnian temperate stage, so that the Anglian cold stage is evidently between the Cromerian and Hoxnian temperate stages. The Hoxnian has a very characteristic vegetational sequence, and its deposits have been found overlying Lowestoft Till at other sites in Suffolk, e.g. Saint Cross South Elmham. They have also been found on the bluish chalky boulder clay of central Norfolk at Barford (Cox

and Nickless 1972), from which a pollen sequence has been studied by Miss L. Phillips, so that this till must also belong to the Anglian stage. According to Banham (1970) the tills of the coastal sections of north-east Norfolk are again to be included in this stage.

It is in the consideration of the post-Hoxnian sequence that controversy arises. The view that it was followed by an ice advance (Gipping advance of the Wolstonian cold stage), then a further interglacial (Ipswichian temperate stage), and finally the last glaciation, has been contested by Cox and Nickless (1972), who consider that there is no evidence in central Norfolk for a Wolstonian advance, and that the Hoxnian deposits in the area accumulated during the early part of an interglacial, the latter part of which may be represented by the Ipswichian deposits of other parts of East Anglia. Here we may point out that the vegetational sequence of the Ipswichian is very different from that of the Hoxnian, so that Ipswichian deposits can be distinguished from Hoxnian deposits.

An important point here is that at Hoxne the temperate interglacial deposits are succeeded by beds with a flora indicating cold conditions - a flora which must be included in the following cold stage. At several sites temperate Ipswichian sediments are underlain by sediments with a herb flora, which must be included in the preceding cold stage. We therefore have clear evidence of a cold stage between the Hoxnian and Ipswichian, and it seems reasonable to correlate this with the Wolstonian. Whether any glacial or periglacial deposits can be referred to this cold stage in East Anglia is discussed later.

Before we do this it is necessary to consider briefly the stratigraphical position of Ipswichian deposits in Norfolk. The Mundesley River Bed lies in a valley cut in the glacial sequence. At Beetley, interglacial deposits lie on coarse flint gravel arranged in a moundy fashion, within a valley. At Swanton Morley, interglacial deposits occur

below terrace gravels of the Upper Wensum. At Wortwell, interglacial deposits lie in gravels within the Waveney Valley. The first three of these sites have been studied by Miss L. Phillips, and the results are in course of publication.

All these Ipswichian deposits lie within valley systems, which must have largely originated before the Ipswichian. Hoxnian deposits may lie on interfluves (Hoxne) or in valleys (Barford). Where they lie in valleys, the valleys are associated with deep subglacial channels of Anglian age, thus indicating that the present valleys at these sites follow trends set by the old subglacial channels.

Thus the events between the Hoxnian and the Ipswichian include a cold period and a period of downcutting. The problem is - are there any glacial or periglacial deposits associated with this interval?

According to Baden-Powell (1948) and West and Donner (1956) the Gipping Till, identified on a basis of erratics and stone orientation, belongs to this interval. According to Bristow and Cox (1973), there is only one chalky boulder clay and this is pre-Hoxnian. According to Straw (1965), the Marly Drift of north Nortolk, a very chalky boulder clay, belongs to the cold stage between the Hoxnian and Ipswichian. According to Cox and Nickless (1972), all the glacial deposits in central Norfolk belong to the Anglian. At Hoxne, there are coarse gravels overlying the interglacial deposits. These evidently post-date the deposits with a cold flora and pre-date the period of downcutting (West 1956); they may be periglacial (or glacial?) sediments of the cold stage between the Hoxnian and the Ipswichian. At Mildenhall, a till occurs above interstradial deposits which are probably post-Hoxnian (Holmes 1971).

It has also been suggested that the erratic-poor flint gravels of Norfolk may be placed in the Wolstonian

cold stage. Thus Straw (1965) associates the Blakeney-Holt gravels with the Marly Drift. Sparks and West (1964) associated the same gravels with the Wolstonian. On the other hand Cox and Nickless (1972) place the flint gravels of central Norfolk in the Anglian.

It is clear from the fore-going that the following questions need to be answered before these problems can be solved.

1. Is the Marly Drift pre- or post-Hoxnian?
2. Are the deposits at Hoxne and Mildenhall mentioned above Wolstonian in age?
3. Can the gravels or Norfolk be differentiated on their erratic content? (There should be type-sites for particular gravels.)
4. If they can be differentiated into, for example, a "cannon-shot" type and types with different erratic suites, how will the gravel stratigraphy fit into the till and interglacial stratigraphy?

However, in spite of these doubts associated with the Hoxnian to Ipswichian stratigraphy, there seems to be general agreement on the last (Devensian) glaciation sediments of Norfolk. They include the Hunstanton Boulder Clay and its associated outwash, and certain low terrace deposits of the valleys.

The final point of confusion attends the matter of correlation of the cold stages with those of the continent. According to those who have studied the vegetational history of interglacial stages in north-west Europe, the Hoxnian is to be correlated with the Holsteinian of north Europe, and the Ipswichian with the Eemian. It follows that the Anglian cold stage is to be correlated with the Elster, and the Wolstonian with the Saale. Other views have recently come forward, Bristow and Cox (1973) have suggested that the Anglian is to be correlated with the Saale, as they consider there is only one widespread chalky boulder clay predating the last

glaciation till. Woodland (1970) considered that the "Great Chalky Boulder Clay" of East Anglia was likely to be of the last glaciation age, on account of the similarity of the subglacial drainage system and the topography with last glaciation regions of Denmark. These views need to be carefully considered, but it is difficult, at least for me, to see how they can overturn the substantial amount of biostratigraphical evidence on which the interglacial correlations are based. A final word of warning is necessary on the matter of correlation with the continent. It is by no means clear that the sequence of temperate and cold stages is in anything like its final form in East Anglia or on the continent. It may be far more complicated than we now know. The present state of correlation is necessarily based on present evidence, but we should always keep an eye open for further complications.

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A POSSIBLE MECHANISM FOR INVOLUTIONS IN THE NAR VALLEY

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Introduction

Involutions are a common feature of periglacial areas, and normally occur in the finest grades of sediment. Those of the Nar Valley are distinctive because they occupy a surficial zone in which intensely weathered Carstone has been reduced to a mass of blocks in a matrix of sand. The involutions, which lie dominantly within this weathered mass, appear to have partially lifted joint blocks of Carstone away from their attachment to in situ bedrock. Some involutions also appear to have been affected by solifluction which has resulted in collapsed involuted forms.

Description

The area consists of an east-west striking ridge of Carstone on the northern side of the Nar Valley (Fig.1). Against the southern side of this ridge are banked a series of sands and gravels up to 8 metres in thickness. These sediments thin rapidly to the west and across the ridge itself. The site studied was in the Blackborough End Gravel Pit and extended for 12 metres on a NNW - SSE alignment.

Succession (see Fig. 2)

G.	Top soil.	0.67 m
F.	Head deposits of angular to sub-rounded fragments of Carstone within a matrix of well washed medium-grained sands. Many of the flints have been frost-fractured in situ.	1.34 m
E.	A mixed series of both sorted and unsorted buff sands which form thin lenticular masses. Sorting is indicated by fine laminae of dark brown granular Carstone.	

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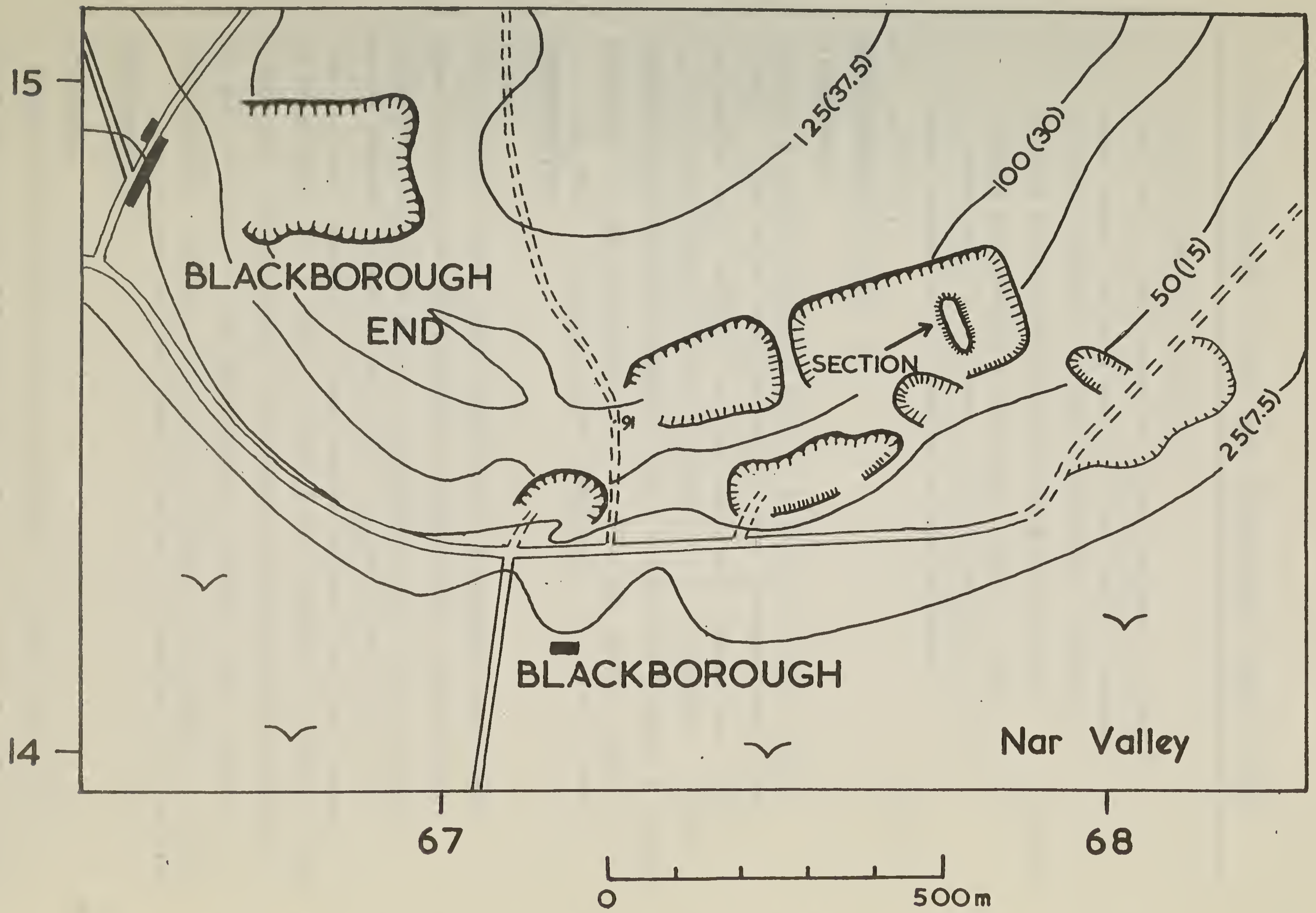

Fig. 1. Sketch-map of the Blackborough area. National Grid 1km. co-ordinates are shown. Contours are given in feet, metric equivalents in brackets.

D.	Medium to coarse well washed light yellow sands with small scale cross-bedding overlying an erosion surface.	0.26 m
C.	A bed of intensely weathered Carstone which has been reduced to coarse red-brown granular sand with a high limonitic fraction. Alternating red and yellow sandy bands are noted in part of the bed which probably form part of a structural B Horizon.	1.40 m
B.	The massive Carstone varies in texture from limonitic boxstones at the base to a weathered rubbly fraction at the top of the bed.	2.65 m
A.	A transition bed of banded yellow and red coarse sands with some nodular bands of Carstone. This bed marks the base of the Carstone with the Sandringham Sands below.	

The massive Carstone has been subjected to intensive weathering under periglacial conditions in which macrogelivation (Tricart..1956) has fully exploited both joints and bedding planes. This has resulted in block disintegration within the Carstone subsurface, and to a lesser extent granular disintegration. The differential effect varies with the lithology since the limonitic rinds of box-stones are reduced to well defined angular blocks highly resistant to further freeze-thaw. In contrast, rubbly Carstone blocks are often honeycombed in texture and present an open system for granular disintegration. The size of block varies with the intensity of weathering, but an average size within the upper 30 cm. of the Carstone would be about 6 x 3 x 1 cm.

The granular Carstone of Bed C forms a deeply weathered zone on the lower slopes of the ridge. In this particular section the sediments are largely disrupted by cryoturbation but some traces of alternating bands of yellow sand and ferruginous clayey sands were found. The

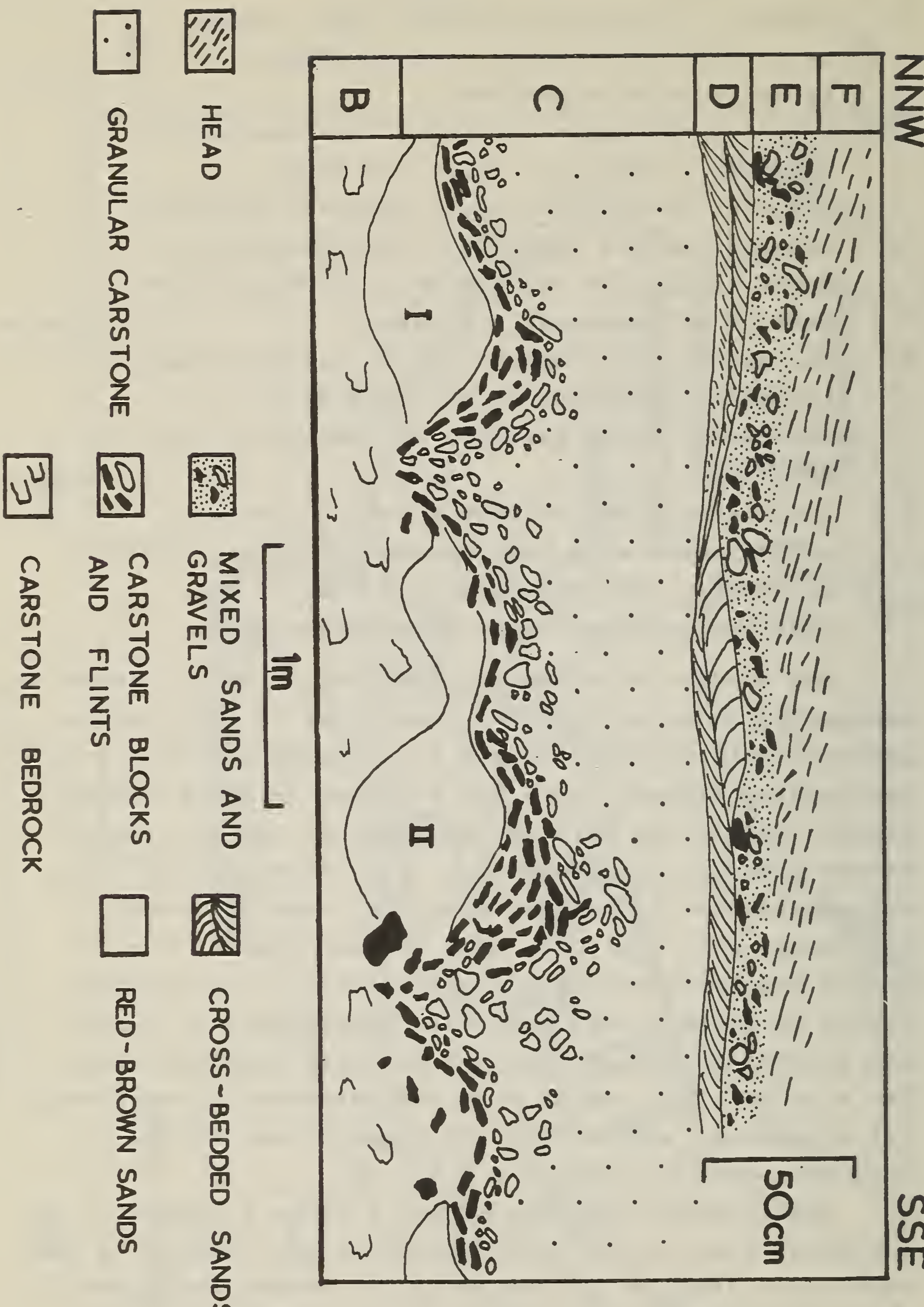

Fig. 2. Measured drawing of involutions within the northern part of the section.

latter are plastic when wet. A comparison with other sections showed that the banded sands were a product of weathered Carstone. Microscopic examination of the yellow sands revealed a high proportion of fractured quartz grains, which indicated that mechanical breakage in situ had been effective. It is possible that this bed is a textural B Horizon which formed when the slope was fully vegetated and stable.

The cross-bedded buff sands of Bed D show considerable lateral variation throughout the quarry. In this section the bed is in contact with an erosion surface, but elsewhere it can overlie a sequence of poorly sorted outwash sands and gravels. The mixed sands of Bed E pass up to subangular to subrounded Carstone which probably represents a solifluction head. Examination of the Carstone within this bed showed a high percentage of conglomeratic Carstone which was probably derived from higher up the succession to the north, and transported downslope under active slope processes.

Periglacial Structures

The involutions extend for some 12 metres within the granular Carstone of Bed C along a NNW - SSE alignment. The term involution core is interpreted as that part of the surficial layer where sag or U-shaped deformation (Watson 1965) has developed, while adjacent anticlinal flexures, which partly enclose the involution core, are referred to as core walls. The involutions have no surface expression within this section but show an increasing degree of instability to the SSE with resulting deformation.

Involutions in contact with the bedrock (Fig. 2)

Length of section: 4.5 metres.

1. The involution cores consist of well compacted flinty gravels and cobbles within a matrix of medium red-yellow and red-brown sands. The cores are open-ended at the contact with the in situ bedrock of Bed B.

2. The core walls are composed of well aligned weathered blocks of Carstone capped by aligned flint cobbles, many of which have been frost fractured in situ. The high dip of blocks within south facing core walls give a recumbent form to the anticlinal flexures, the latter having an amplitude of 80 cm.
3. The recumbent structures overlie elliptical pockets of red-brown sands (Fig.2, I and II).

<u>Involutions detached from the bedrock</u> (Fig. 3)

Length of section: 5.0 metres.

1. Only one involution core is observed within this part of the section.
2. The amplitude of structures is much reduced compared with those described above, and is generally less than 50 cm.
3. The involution form is mainly lacking and replaced by a complex sequence of overturned Carstone blocks with some evidence of décollement towards the SSE of the section.
4. Bed C1 (Fig. 3) consists of red-brown sands with scattered Carstone blocks and fine gravel, the sands are similar to those of the elliptical pockets (Fig. 2, I and II). The basal 20 cm is made up of dark blue-brown granular Carstone indicating recent weathering in situ. Bed C1 has been disrupted by yellow-red gravelly sands in the form of a discrete trail and two elongate pockets.

<u>Interpretation</u>

There have been many papers describing the mechanics of frost-heave in the grained sediments, but few for coarser material. Previous workers have attributed the uplift of weathered bedrock to different mechanisms. These include folding due to weathering (Campbell 1906), drag or slide due to glacial movement (Sardeson 1905), upheaval due to frost action (Sardeson 1906), and uplift due to hydro-laccoliths (Bradshaw and Ingle-Smith 1963). The following

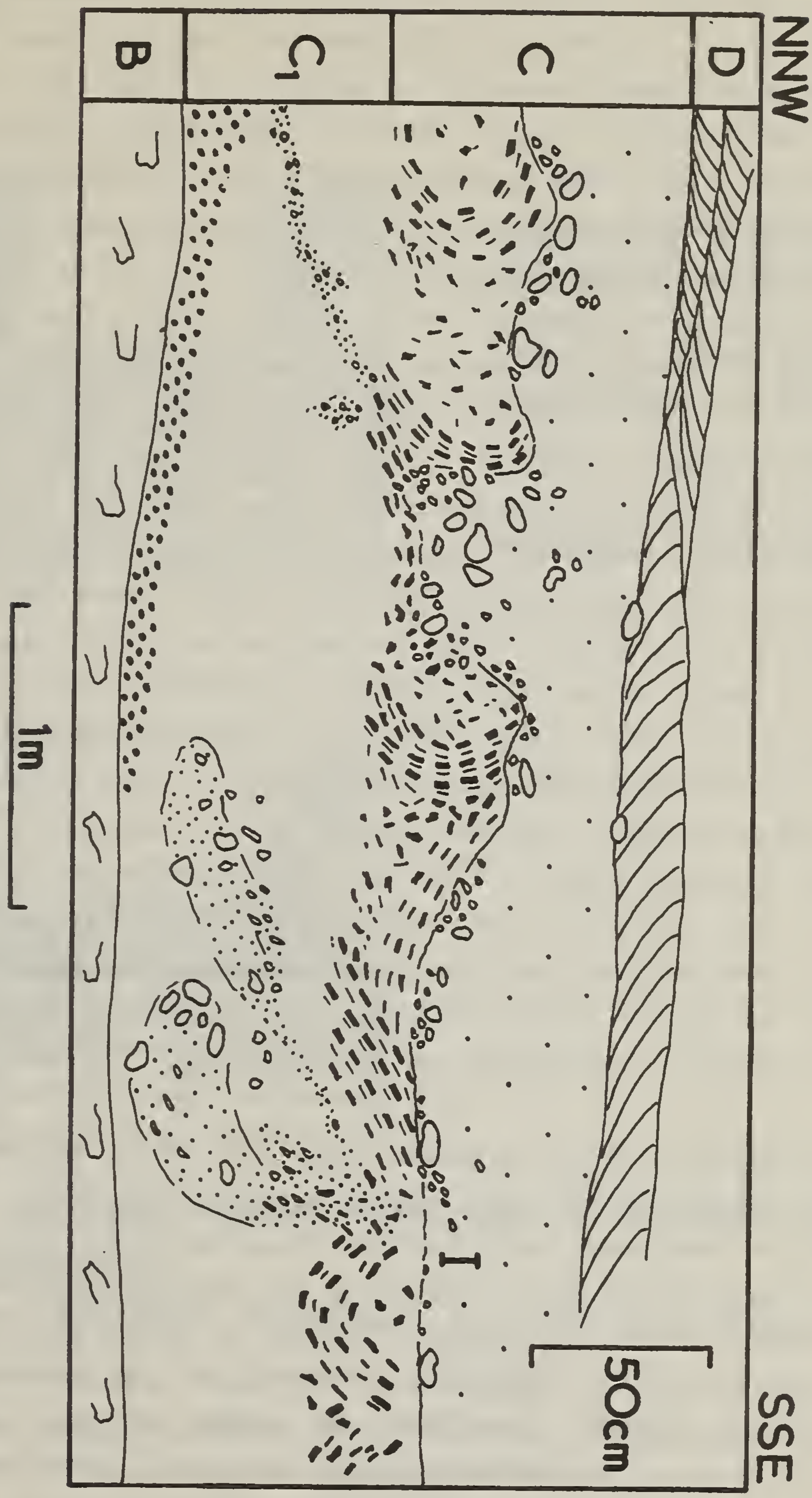

Fig. 3. Southern part of section showing main features of deformation within the involuted layer. Key to beds as for Fig. 2. Heavily dotted area, Basal Bed C1, denotes granular Carstone.

account considers forceful intrusion and differential sorting as the possible mechanism for involutions.

The subsequent removal of material from this site showed the disposition of involutions in many stages of development along the upper surface of in situ bedrock. It was found that involution cores were subjacent to downward penetrating irregularly shaped pockets of red-yellow sands with vertically aligned cobbles and gravels. One section revealed four descending pockets, the largest being 0.40 x 0.25 metres, within a horizontal distance of 2.5 metres.

At the point of contact with the Carstone surface the weathered blocks were depressed by the lodgement of descending sand and gravel pockets, and formed the subsequent involution core, (Figs. 4a and b). The combined effect of this at several points of contact was to produce low amplitude anticlinal flexures, the core walls, as a result of compensatory upward movement. Apart from some granulation within the core walls there was no evidence to indicate partial uplift from the segregation of fine grained masses. The amplitude of core walls was never greater than 25 cm. Similar successions were examined in order to clarify the relationship between the Carstone subsurface and the initial formation of involutions. It was found that:

(i) Weathered blocks greater than 2.0 cm in thickness resisted the forceful penetration of gravels.

(ii) Where vertical jointing had been greatly weathered the penetration or collapse of overlying gravels formed "Neptunean dykes" up to 38 cm in width.

(iii) Partial uplift appeared to be most effective where shattering had increased the overall joint system, and reduced block thickness to less than 1.5 cm (see shattered Zone Fig. 4b). In this state the forceful lodgement of gravels was restricted to a depth of 35 cm by the permafrost table.

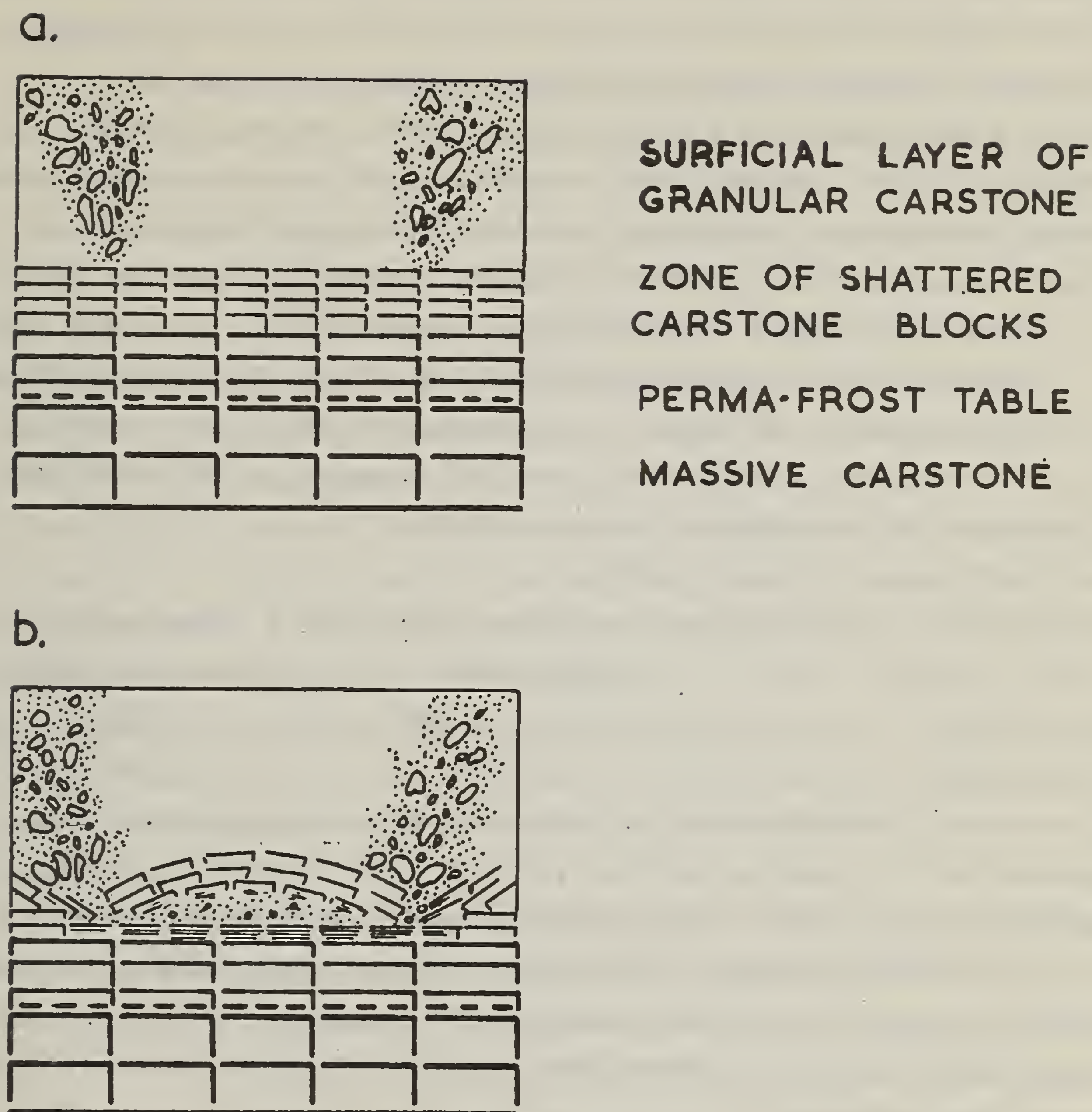

Fig. 4. Schematic sections illustrating a possible mechanism for involutions.

(a). The downward migration of sand and gravel pockets in advance of a freezing surface.

(b). The partial uplift of shattered blocks and proliferation of the sand fraction.

Further development of involutions appeared to be relative to the lateral migration of sands and finer gravels away from the involution core (Fig. 4b). The grade of the migrating material was effectively controlled by the close disposition of blocks within the base of core walls, while depleted involution cores became highly compacted with gravels and cobbles. It is advocated that lateral migration resulted in the eventual formation of elliptical pockets, and that these acted as centres for ice segregation and differential heave (Fig. 2, I and II).

Samples were taken from both the periphery and centre of these pockets in order to determine the percentage of fines (less than 0.074 mm), and to compare them with the sediments of involution cores and Bed C.

Bed C (fines averaged 2.5%).

Involution cores (fines less than 1% in all samples).

	Periphery	Centre of Pocket
Fig. 2, I.	1.5 - 2.0%	2.6%
Fig. 2, II.	2.0%	3.3%

Microscopic examination of all grades sieved revealed aggregates of quartz grains cemented by limonite, and indicated that the fines were probably under-represented in the sieve analysis. The results not only indicate that the percentage of fines increase downwards, but there is a significant increase from depleted involution cores to the centre of pockets.

It is considered that the dominant mechanism during the initial phase was the downward migration of gravels in advance of a freezing surface. A.L.Washburn (1950) has proposed cryostatic pressure for such a process in patterned ground, but those studied have no surface expression. To some extent cryostatic pressure is envisaged but accompanied by differential sorting within the active or surficial layer (Sharp 1942). Since the percentage of fines increase downwards it is likely that these migrated with the freezing surface (Corte 1963),

with additional fines also produced at the permafrost table since moisture tends to concentrate at this surface. This is particularly evident from the underlying pockets of core walls.

Since the involution cores terminate abruptly at the bedrock surface it is unlikely that the compensatory uplift of core walls would have been great. Observations of the initial height of vertical movement is about 25 cm. Therefore the progressive uplift of blocks has probably resulted from the lateral migration of sands from involution cores to form ice segregation centres (Fig. 2, I and II). Repeated freezing and thawing within these centres would segregate the fines necessary for differential heave. S. Taber (1929) regards 3% fines as too small for differential heave, but T. L. Péwé (1962) considers such a figure minimal for heaving to occur, the latter does not indicate the degree of heave taking place. This author considers that the relationship of involution form to segregated pockets suggest differential heave as a likely mechanism rather than one which is pure congelistic.

The deformation of involutions and subsequent collapse of core sediments in Fig. 3 can be partly ascribed to active slope processes. The Carstone subsurface has been subjected to a greater depth of weathering resulting in slope retreat with a downslope angle of two to three degrees. A distinct break in slope separates those completely detached. Therefore the marked structural trend of deformed involutions down-slope is probably the result of solifluction under conditions of saturation during the spring-summer thaw.

The recently weathered granular Carstone (Bed C1, Fig. 3) confirms that weathering continued to be an active process after deformation, and to some extent explains the apparent height to which blocks appear to have become detached. It is also considered that

detachment was contemporaneous with solifluction since slip would have possibly effected the lateral spread of segregated centres below the involution walls. The red-brown sands of Bed C1, Fig. 3 are similar to those found in Fig. 2, I and II. These sands (Bed C) have been intruded by two pockets of gravels and cobbles within a matrix of red-yellow sands, the latter being similar to those found in all involution cores within the section. The pockets have sharp contacts, and both are aligned upslope and sub-parallel to a trail of similar sands. There is a marked absence of cobbles capping the collapse structures in that part of the section (Fig. 3, I).

The sharp contacts of these pockets indicate that entombment was rapid. Therefore under conditions of extreme saturation the medium coarse sands of involution cores would be less cohesive and heavier (Williams 1959). This state of instability is likely to be activated by slip within the surficial layer so that the collapse of involutions cores would result from the rapid downward migration of sands into Bed C. S. Dzulynski et al. (1964) considers that such disturbances are caused by spontaneous liquefaction under hydrostatic pressure. Similarly, P.H. Keunen (1958) proved experimentally that canoe-shaped structures are indicative of rapid entombment from vertical motion of the 'load-cast' type.

The additional water required for supersaturation is relative to the height of the water-table. Exposures in the northern part of the ridge reveal large fissures, up to 1.0 metres wide at a depth of 6 metres, which have developed along joint planes. These would allow sufficient circulation of ground water to carry heat to considerable depths, thus effecting an extensive thaw during the summer months.

Conclusions

1. The involutions were initially formed, under periglacial conditions, from the downward migration of

sands and gravel pockets in advance of a freezing surface. The impingement of these pockets on the Carstone surface resulted in the depression of weathered blocks to form a site for the involution core. The partially uplifted blocks of core walls are in part a compensatory response to the lodgement of the core, but to a greater extent from the lateral movement of sands away from involution cores to form centres for ice segregation. Differential heave from repeated freezing and thawing within these segregated centres uplifted the involution walls through a greater height.

2. The involutions were then subjected to solifluction which deformed the existing structures, and resulted in the collapse of core sediments into the bed below. The rapid entombment of these sediments was probably due to vertical motion, the 'load-cast' type, under conditions of supersaturation.

The peculiar form of these involutions was confined to a small area of Blackborough Pits, and is therefore regarded to be of local significance only. The association of deep weathering of joints to form fissures, ice wedges, frost kettles and stone stripes is under review.

Acknowledgement

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THE BASE OF THE CARSTONE AT HUNSTANTON

R. W. GALLOIS*

Introduction

The familiar rusty-brown Carston of Hunstanton Cliffs needs little introduction to the student of East Anglian geology. The details of the lithology of the Carstone and of its junction with the overlying Red Chalk have received considerable exposure in the geological literature. By contrast, the base of the Carstone and the nature of its contact with the Snettisham Clay, because of its poorly-exposed position low down on the foreshore, has rarely been described. Even the few accounts that do exist leave considerable doubt as to where the Carstone ends and the underlying clays begin.

Rose (1862, p.235) described the Carstone on Hunstanton beach as a 'breccia', saying that it had been considered to be the base of the Lower Greensand but that at low water he had found a non-brecciated bed beneath the breccia and saw this bed resting on a clay (presumed at that time to be the Kimmeridge Clay).

Wiltshire (1869, p.189) recorded a nodule bed, made up of two distinct types of nodule, at the junction of the Carstone and the clay. The first type of nodule, of unstated lithology, contained numerous Ammonites Deshayesi and occasional A. Cornuelianus (Prodeshayesites and Cheloniceras of modern authors); the second type of nodule consisted of masses of ironstone and yielded A. Cornuelianus and many bivalves. He concluded from these faunas that the lowest part of the Carstone was equivalent in age to the base of the English Lower Greensand.

Keeping (1883, pp. 33 and 57) reviewed this and other collections from the same beds and gave further details of

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* Institute of Geological Sciences, London S.W.7, published by permission of the Director.

lithologies and faunas of the nodules. The first type he described as rolled phosphatized casts containing Lower Aptian ammonites which he considered to be entirely derived. The second type consisted of concretions of dark-coloured ferruginously-cemented fine-grained sandstone 'as big as large cannon-balls' and 'crowded with casts of fossils'. The fossils were mostly bivalves, but included fragments of an ammonite described as '*Hamites* or *Ancycloceras*, small species with a double row of spines along the back' (p.33).

Whitaker and Jukes-Browne had little to say about the nature of the base of the Carstone in the Survey memoir on the borders of The Wash (1899), although the underlying clays had by now become recognised as 'Lower Greensand' in age and were assigned by them to the Snettisham Beds (p.6).

The first, and possibly the only, published description of a section through the base of the Carstone at Hunstanton is that of Lamplugh (1899, p.20) who recorded about two feet of 'pebbly yellow Carstone with yellow phosphatic fragments and fossiliferous dark brown phosphatic nodules', the nodules containing *A. Deshayesi*, probably underlain by 'green clayey sand, with scattered coarse pebbly grains'. He concluded that the fauna of the nodules was at its proper horizon and that the lower part of the Carstone was equivalent in age to the upper part of the Atherfield Clay or to the lower part of the Hythe Beds (p.21). These are clearly the same nodules as those containing Keeping's derived fauna, but no mention is made of the iron-grit nodules.

More recently, Casey (1961, p.571) has re-examined many of the old collections from the phosphatic nodule bed, together with material collected over many years by Mr. Hamon LeStrange of Hunstanton, and has shown the ammonite assemblage to be composed of two faunas, both Lower Aptian in age, from the Zones of *Prodeshayesites fissicostatus* and *Tropaeum bowerbanki*.

In 1970 the Institute of Geological Sciences drilled a cored borehole at Lodge Farm, Hunstanton (TF 6857 4078), about $1\frac{1}{2}$ Km ESE of the beach sections described below, to examine the Lower Cretaceous sequence. The cores threw little light on the nature of the Snettisham Clay - Carstone junction, and the base of the Carstone was placed at a change from pebbly oolitic clays to pebbly oolitic sands. No phosphatic nodule bed was seen and the section appeared to bear little relation to those of the published literature.

This was the rather unsatisfactory situation that led Mr. LeStrange generously to hire a mechanical digger to expose part of the Snettisham Clay - Carstone contact. As a result, about twenty members of the Geological Society of Norfolk, together with assorted shovels, sieves and a JCB 3C, gathered on Hunstanton beach at low tide on the morning of October 22nd., 1972.

Stratigraphy

The first and second attempts to obtain sections, a little to the south and to the north of the pier respectively (Fig. 1), were at spots indicated by Mr. LeStrange as being on the line of outcrop of the base of the Carstone as he remembered its position when it had been visible in the 1930s. Both excavations passed through a metre or more of beach sands into waterlogged flint gravels and the holes collapsed.

A third excavation adjacent to the outer Carstone reef (TF 6714 4160) was more successful and proved weathered pebbly Carstone resting on very pebbly dark grey sandy clays containing many limonitized ooliths. No phosphatic nodule bed was seen and although the section could be matched in some detail with that of the Hunstanton Borehole, this was not particularly helpful.

The fourth, and final, section dug adjacent to the same reef (TF 6715 4177) was the most successful and work in it, and on the spoil derived from it, occupied the

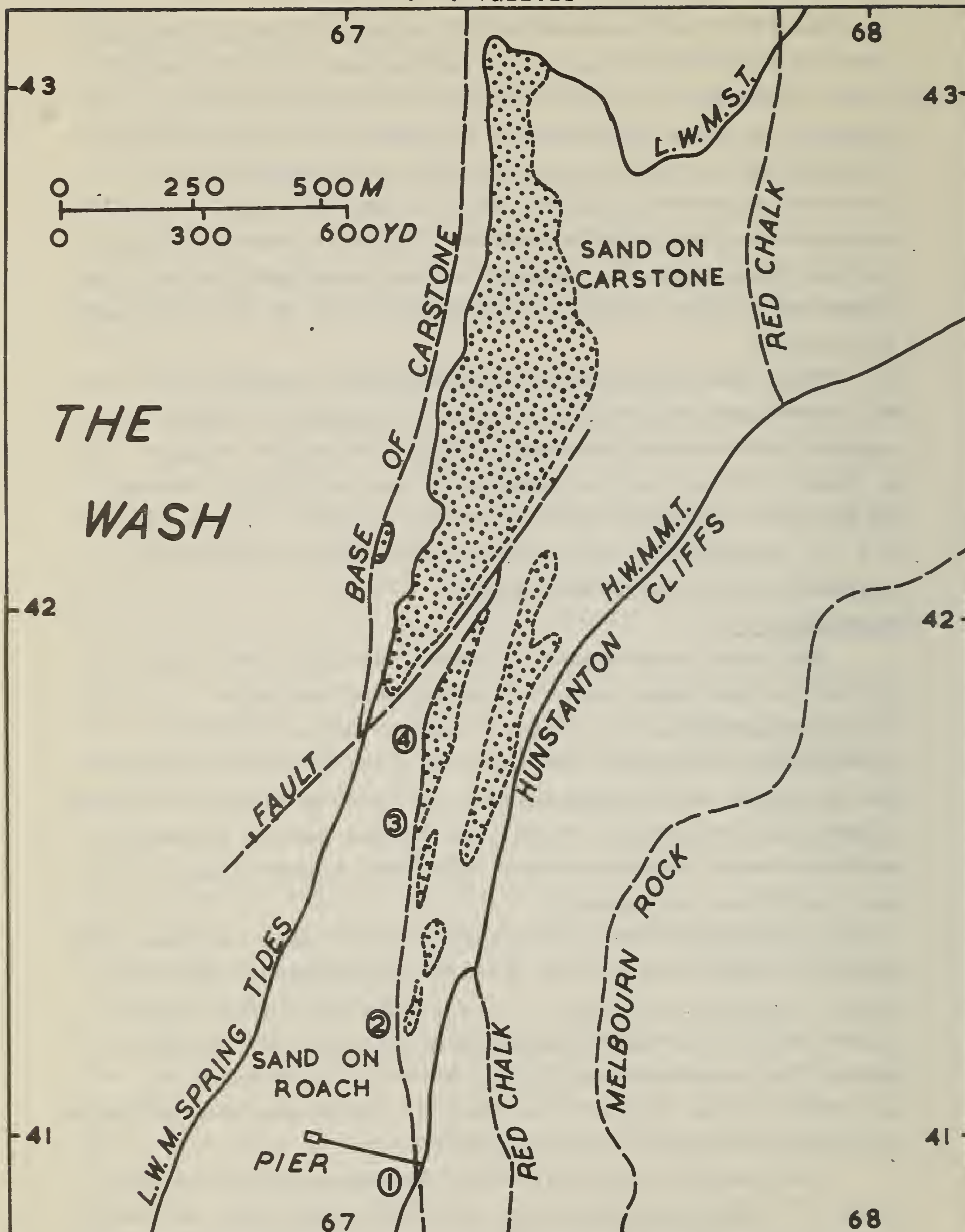

Fig. 1. Geological sketch map of Hunstanton Beach in 1972 showing Carstone outcrops (stippled) and sites of excavations 1 to 4.

greater part of the day. A trench about 0.6m x 2.5m x 3.2m deep was excavated and the following section recorded:

	Recent beach sand	0.30 m
5.	Fine-grained orange-brown, moderately pebbly, oxidised and rotted ferruginous sandstone	0.30 m
4.	As above but very pebbly and including widely spaced (0.5m to 1.0m apart) dark brown generally well rounded phosphatic nodules (up to 0.1m across, but mostly 0.02 to 0.03m), some of which contained worn specimens of ammonites; ferruginous seepage at base	0.15 m
3.	Dark grey sparsely pebbly, moderately oolitic (chamosite, largely oxidised to limonite) intensely burrow-mottled clay	0.76 m
2.	Dark grey very pebbly, moderately oolitic, slightly sandy clay; very sharp plane base	0.30 m
1.	Pale and medium grey intensely burrow-mottled fine-grained sands and very fine-grained clayey sands; burrow fills of fine and medium-grained greenish yellow sand extend down for about 0.5m from the base of Bed 2; fragments of coalified wood scattered throughout; widely spaced dark greyish brown sandy ferrugino-phosphatic nodules, mostly burrow fill shapes, up to 0.2m across and some containing moulds of small bivalves, rarer gastropods and bits of wood, occur in the lowest 0.5m (not seen *in situ*); small irregular sandy pyrite concretions occur more rarely at about the same level	1.37 m

Bed 5 is a continuation of the outer Carstone reef and, as with the reef, the chamosite oolite part of the rock has been completely oxidised to limonite.

The phosphatic nodules in Bed 4 yielded fragments of species of Prodeshayesites, Cheloniceras and Dufrenoyia, being part of the re-worked Lower Aptian fauna referred to above. The absence of these nodules from the third excavation and their wide spacing in the fourth explains the difficulty experienced in the Hunstanton Borehole. The large numbers of ammonite fragments derived from this bed which occur scattered along the outer Carstone reef suggest that elsewhere along their outcrop the fossiliferous nodules are more densely packed than was seen in the excavations. Larger rough-coated phosphatic nodules (up to 0.12m across), with sandy cores and often with ooliths, sand grains and pebbles stuck to their outer surfaces, also occur in Bed 4, but these appear to be unfossiliferous. Many appear to take the form of burrow fills.

Keeping's iron-grit nodules were not seen in any of the excavations but Mr. LeStrange collected several nodules, whose lithology closely fits Keeping's description, from an exposure near the pier in the 1930s. These nodules, now in the British Museum (Natural History), are composed of dark brown sandy phosphatic ironstone, crowded with moulds of tiny bivalves (e.g. BM Nos C 35512 and C 35238). The original nodules were well-rounded and up to 0.20m across, but have now been broken up to reveal the fauna. In addition to the bivalves, fragments of coalified wood are relatively common and a few ammonite fragments are present. These latter have been described by Casey (1961, p.571) as 'Barremian ammonites of the genus Paracrioceras and as being the same as the 'Hamites or Ancycloceras' of Keeping. The nodules were distinctly rare even when the base of the Carstone was well exposed and, according to Mr. LeStrange, occurred in small groups in a clay about 0.15 m below the base of the Carstone (i.e. in Bed 3 of the excavation).

Bed 3 is clearly that recorded by Lamplugh and previously taken to be the Snettisham Clay. The pebbles and ooliths within this bed and within Bed 2 are identical

to those which made up a large part of the typical Carstone lithology. The junction of Beds 3 and 4 in the excavation was obscured by ferruginous seepages and by oxidation, and in the Hunstanton Borehole's cores by intense burrowing. However, Beds 2 and 3 appeared, in both sections, to pass up by addition of pebbles and sand into Beds 4 and 5. The only clear sedimentary break in both the excavation and the borehole section was at the base of Bed 2. It would be possible therefore, on lithological grounds alone, to consider Beds 2 and 3 as part of the Carstone. The increase in pebble concentration and the sudden appearance of the re-worked Lower Aptian fauna in Bed 4 suggest a marked increase in the energy of the sedimentary environment at the base of Bed 4, probably accompanied by a much wider area of sediment source. The presence of a Barremian fauna in the iron-grit nodules is not in itself conclusive proof of the age of Bed 3 since the nodules are themselves probably re-worked. The Carstone is considered at the present time, on indirect evidence, to be Lower Albian in age and it would be curious, assuming Beds 2 and 3 were taken as part of the Carstone, if a re-worked Barremian fauna were to appear before a re-washed Lower Aptian fauna in beds of Albian age. The simplest interpretation, until more palaeontological evidence is available, would be to assume that Beds 2 and 3 are part of a separate formation, different from both the Carstone above and Bed 1 below, of Barremian or younger age.

At the base of Bed 2 there is a marked lithological change; in the beach excavation burrow fills of Carstone lithology sand extend down from the base of Bed 2 in much the same way that, southwards from Hunstanton (where the Carstone rests on progressively lower parts of the Lower Cretaceous) burrow fills of Carstone penetrate the Snettisham Clay at Leziate (TF 684 194) and the Sandringham Sands at Blackborough End (TF 677 144). In the Hunstanton Borehole, where an almost identical sequence of

lithologies was recorded, this junction appeared to channel down into the underlying sands (Fig. 2). The sandy nodules contain traces of bedding and burrow mottling and appear to have accreted in situ around burrows and to have preserved part of the indigenous fauna of the sands. Unfortunately most of this fauna is indeterminate but it does include an ammonite fragment which can be matched with the Paracrioceras of the iron-grit nodules both in form and in mode of preservation. Indeed the whole fauna and lithology of the nodules from Bed 1 is very similar to that of the iron-grit nodules, except that the latter are more fossiliferous, more densely cemented and more finely sandy.

In the Hunstanton Borehole section the sands correlated with Bed 1 form part of a complex sequence of sands, clays and pebbly oolitic clays which can be lithologically matched with the Roach of Lincolnshire. In the borehole this sequence overlies, without obvious disconformity, clay of similar lithology to that of the Snettisham Clay of the Heacham - Snettisham area, which latter has yielded a fauna of Lower Barremian crioceratid ammonites (Spath 1924, p.79). It seems likely therefore that Bed 1 will prove to be Middle or Upper Barremian in age.

The clays referred to by Whitaker and Jukes-Browne (1899, p.12) found in sinking piles for the pier probably also belong with the Roach. The true Snettisham Clay probably crops out some way below the lowest tide mark and has never been seen at Hunstanton. The Roach clays are cut out southwards from Hunstanton by the Carstone overstep and, with one possible small area of exception in the valley of the Barrett Ringstead Stream (TF 679 393), do not crop out in Norfolk.

Acknowledgements

It should now be clear that the field meeting to which this account relates would not have taken place but for the enthusiasm and generosity of Mr. Hamon LeStrange. He not only suggested, financed and organised the excavations but

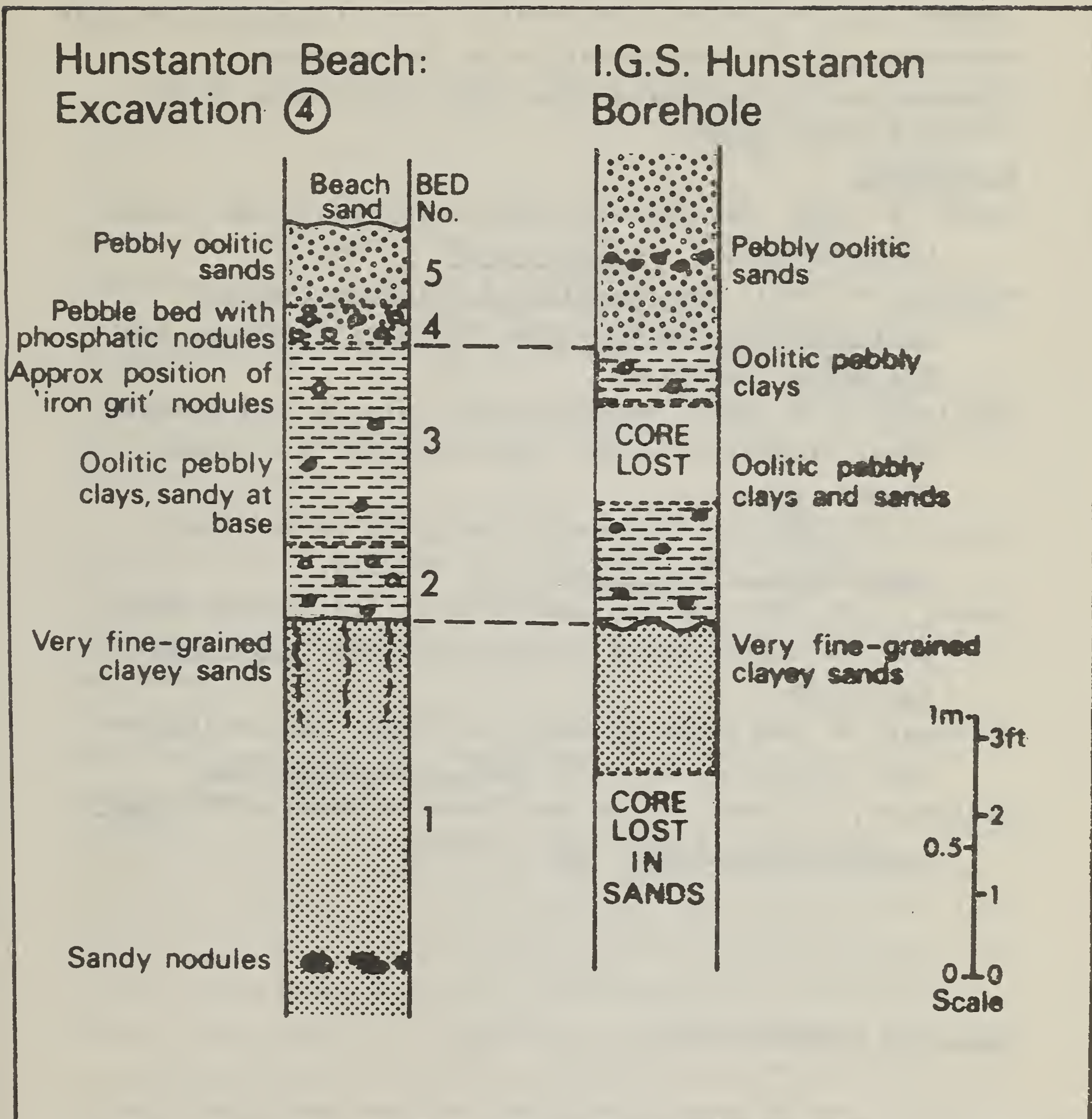

Fig. 2. Lithological comparison between the beach section and the Hunstanton Borehole.

his local knowledge of Hunstanton beach was essential to their success. In addition, the preparation of this account has been made considerably less difficult, and less ambiguous, by the incorporation of his personal observations on exposures long since covered up by the drifting beach sands.

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EARTH SCIENCE TEACHING AT THE OPEN UNIVERSITY

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In the middle of 1969 a small group of Open University academics and administrators had to decide how to prepare degree courses which could be taken by students working largely independently at home. In science, nine faculty members had the additional problem of how to provide adequate practical science experience to students working at home. In addition the two geologists amongst them had to begin to think how to teach Earth Science 'at a distance', and in particular how to provide adequate field and practical experience for students wishing to study in the Earth Science area.

In less than two years the system of teaching was devised, and if success can be judged by the Open University's current enrolment of 42,000, sales of its materials and their use in other educational establishments, and numerous visitors to the campus, then we have been successful. Our system works well, but it is by no means perfect, and so it is constantly evolving, and we hope improving.

How was the problem of teaching at a distance overcome? To many people, television would appear to be the medium for such instruction, but in reality the amount of TV time (less than 10 per cent of the student's workload) makes it almost useless on its own. The success of our system is due to the degree of integration achieved between all the components of our courses. Rather than itemise these, an example will demonstrate the concept much better. Part of the Second Level Geology course, which students take after they have finished the Foundation Course (of which more later) involves the study of geological maps.

The 'core' of all Open University courses is the unit

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text, which in the case of the map course is entitled 'Field Relations'. These texts are designed for students working alone, so they are 'structured' accordingly. At the beginning of each text the performance objectives of that part of the course are stated, spelling out to the student what he should be able to do after completing his work that he could not do before (Fig. 1).

Objectives

When you have finished this Block, you should be able to:

1 Define correctly, or recognize the best definitions of, or distinguish between true and false statements involving terms, principles, laws and concepts in the third column of Table A.

2 Demonstrate a working knowledge of map scales, orientation, co-ordinates, contours, dip, strike, and outcrop patterns by successfully carrying out exercises and calculations on geological maps.

3 Construct a topographic and geological section and correctly identify features depicted on it.

4 Identify correctly unconformities on a map, and distinguish them from other types of geological boundaries.

5 Given da... geological stru... rties of rocks ...

Fig. 1. An example of some of the performance objectives for the Field Relations section of the Second Level Geology course.

Next, the concepts and terms in the text with which the student should be familiar are listed in 'Table A' (Fig.2), and this table is always referred to in the list of objectives. Then follows the main text. Figures 3 - 7 show examples from the 'Field Relations' which teach contours. The section starts off with a study comment (Fig. 3), which states the relevant objectives in a more conversational way. The section on contours uses three dimensional cut-out models, which students construct and use in conjunction with the text as instructed (Fig. 4). So this is an example of a simple visual aid linked to a written text. Similarly, the written text can be linked to an item of TV teaching. Figure 5 shows another part of 'Field Relations', which was taught in detail on television with aid of a three dimensional model based on

List of Terms, Concepts and Principles used in Block 2

Taken as prerequisites					
Assumed from general knowledge (GK) or from S100 (Unit No.)		Defined in previous S23 – Blocks	Block	Developed in this Block	Page No.
FR 1					
map scale	GK	Cambrian	3	grid reference	10
National Grid	GK	Ordovician, etc.		solid and drift maps	11
grid reference	GK			geological symbols	11
topographic map	GK				
geological map	GK				
Phanerozoic	26				
FR 2					
topographic contour	GK			geological structure	13
topographic section or profile	GK			outcrop pattern	13
				dip	13
				structure contour	15
				strike	15
				true dip	16
				apparent dip	16
				... 'V's	

Fig. 2. Part of the 'Table A' of the <u>Field Relations</u> section of the Geology course, which indicates to students the terms, etc. they will need to know before reading the text, and the terms, etc. with which they should be familiar after completing it.

FR 2 Plotting Three-dimensional Surfaces in Two Dimensions

Study Comment

This Section introduces the concept of geological maps as two-dimensional representations of three-dimensional topographic and geological surfaces. The intersection of these two surfaces produces a geological outcrop, the pattern of which indicates the form of the geological surface. This is generally described as a geological structure. By the end of this Section you should be able to recognize the basic patterns produced by simple planar geological structures, namely horizontal and dipping strata. The method of drawing topographic and geological sections is introduced.

2.1 Introduction

You are probably used to using maps as an aid in travelling from place to place —on footpaths or roads. But many road maps leave out, or greatly simplify, the topography of the areas they depict, so you may not be too familiar with reading maps which show contours. *All types of maps depict a three-dimen... ...ation in two dimensions o... ...ner.* Photographs do...

Fig. 3. An example of a study comment at the beginning of a section of the <u>Field Relations text</u>, the purpose of which is to remind students of the performance objectives of this section.

2.3 Contours

Contour lines join points of equal elevation on a surface

If you place a pad of ruled paper against a book in the manner shown in Figure 5, the lines on it are topographic contour lines. Or take model 1: on the side of it are marked centimetre intervals—these give the 'altitude' of different parts of the model (Fig. 6a). When these are projected on to the sloping surface of the model, the lines are the *topographic contours* for that slope. On the other side of the model (Fig. 6b) a bed of sandstone is marked, having the same inclination

Figure 5 Ruled pad of paper resting against a pile of books: lines represent contours.

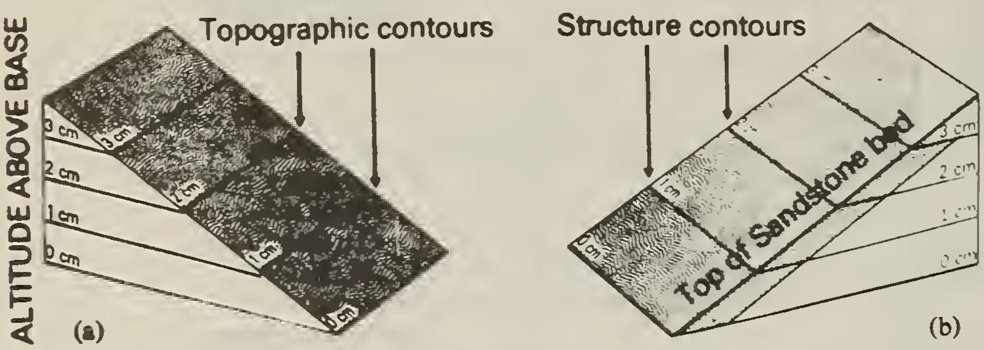


Figure 6 (a) *Model 1, illustrating topographic contours on an inclined planar surface.* (b) *Model 1, illustrating structure contours on the top of an inclined bed of sandstone.*

as the 'topographic surface' of the model—so the whole of the top surface is the outcrop. And the contours are also *structure contours*—they join points of equal elevation on the upper surface of the sandstone. These contours can be projected on to a planar surface, as shown in Figure 7a, using models 1 and 2. Figure 7b shows the *dip* and *strike* directions marked on both models—mark them in on your models. *The strike is the direction, with respect to true north, of a horizontal line in the plane of an inclined bed. It is perpendicular to the direction of the dip.*

structure contour

strike

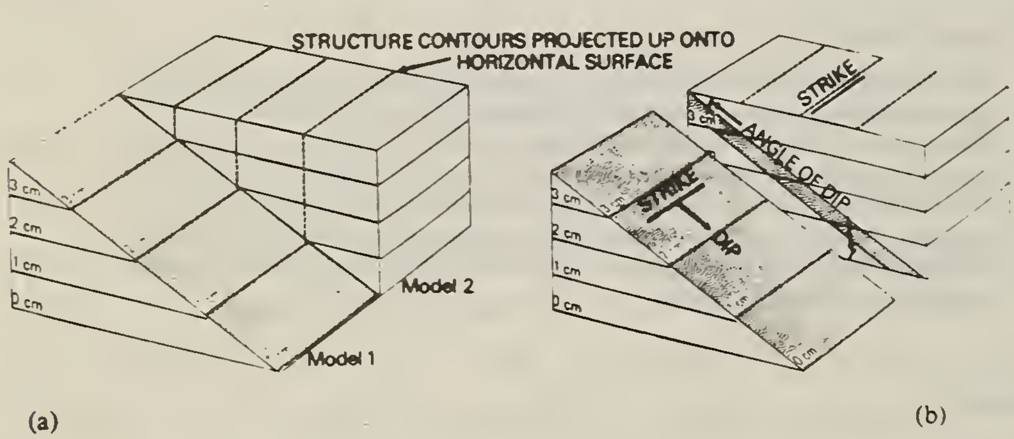


Figure 7 (a) *Projection of contours onto a planar surface.* (b) *Dip and strike directions marked on Models 1 and 2.*

Fig. 4. An example of instructional text linked to simple three dimensional models constructed by students.

2.5 Using contour maps

You are probably already familar with using topographic contour maps. As a check try Question 5.

Question 5 Examine the contour map shown in Figure 10 and answer the following:

(a) In which direction is the river flowing?
(b) Which is steeper, slope A or slope B?
(c) Which is the highest point—X, Y or Z?

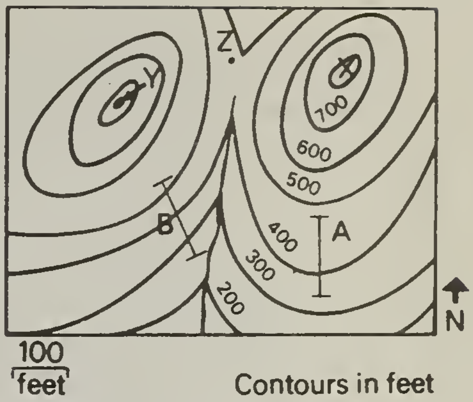


Figure 10 *Contour map for use with Question 5.*

(a) River flows to the south.
(b) B is steeper.
(c) Y (just over 900 feet).

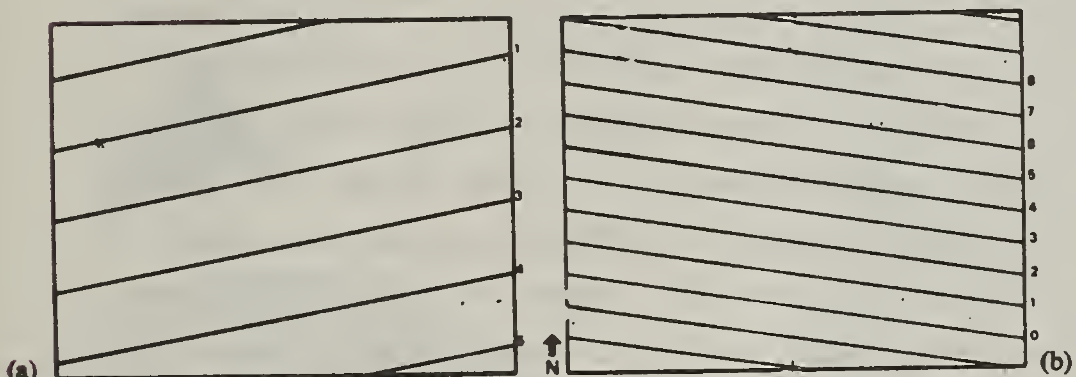


Figure 11 *Structure contour maps for use with Question 6 (inter als of 100 feet).*

Question 6 Examine Figure 11 which shows two simple structure contour maps of a geological surface.

(i) Which map shows strata dipping in a northerly direction?
(ii) Is the surface dipping more steeply in map (a) or map (b)?

(i) Map (a) shows surface inclined to the north.
(ii) Map (b) shows surface inclined more steeply than in map (a).

Question 9 Let us assume that the structure contours in Figure 11b are of a coal seam underlying the land surface shown in Figure 10. Superimpose Figure 10 on Figure 11b by making a tracing, and draw in the outcrop pattern of the coal seam.

The correct pattern is shown in Figure 14. Note again the 'V' pattern—illustrating the law of the 'Vs'—the 'V' points in the direction of dip.

Fig. 5.

(Figure continued overleaf)

While the law of 'Vs' holds in most cases for dipping beds, there are two important exceptions when it does not hold: *horizontal strata*, and strata which dip *downstream* at a *lower* angle than the gradient of the stream will 'V' *upstream*.

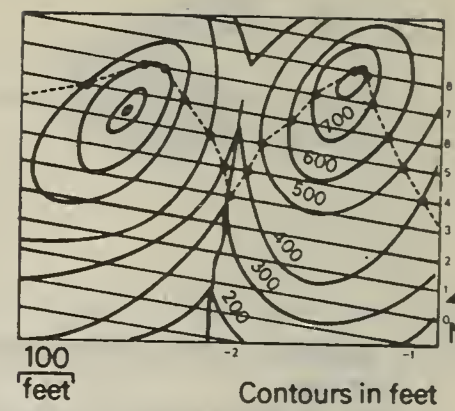


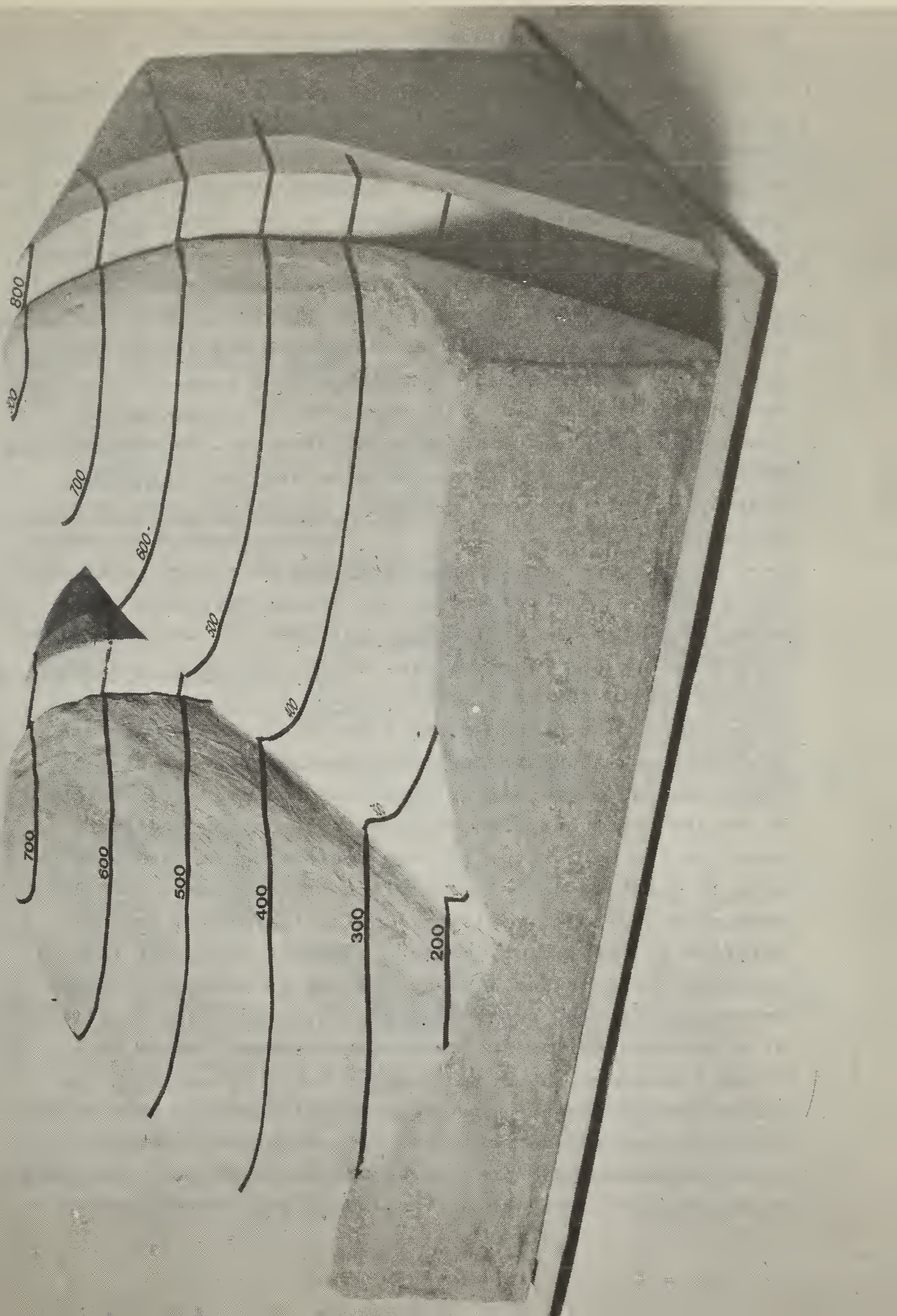
Figure 14 *Solution to Question 9: Outcrop pattern produced from data in Figures 11b and 10.*

Fig. 5. Parts of the Field Relations text showing how it is made 'student active'. Figures 10 and 11 form the basis for a model (Figure 6 opposite) used on a TV programme.

figure 10 and 11b of the text (see Fig. 6). This example from the text also shows how the written word is made 'student-active'; questions are posed in the text for students to work out, and answers are then given in the margin. This is a simple kind of programming, but some times other types of questions are used where answers are given at the end of the text, or self-assessment questions are collected together at the end of the text for the student to check whether he had achieved the objectives stated. 'Field Relations' also uses a collection of five geological survey maps which students purchase; the main text refers to these maps many times and they are also used for assessment purposes. None of the individual teaching methods used is new, but their combination and integration have produced a different kind of teaching method designed specifically for the independent learner.

When students have completed the core of the course, they are assessed either by tutor marked assignments (TMA) or computer marked assignments (CMA). TMAs in the case

Fig. 6. TV demonstration used to teach the concepts of topographic and structure contours.


800
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of the map course involved section drawing, or identifying given geological structures, or writing geological histories from map evidence. These assignments are marked by part-time tutors, who meet students at local study centres to discuss various aspects of the course and the assignments. CMAs involve objective tests, with a student choosing his answer from a number of alternatives (Fig. 7), pencilling out the appropriate letter, and later transferring all his answers to a sheet which is sent off to the Open University headquarters to be marked by a computer - at the rate of 4,000 an hour! CMAs have proved to provide a considerable learning incentive to students, as when working through them they are forced to consider very carefully whether or not they have grasped a particular part of the course.

An introduction to mineralogy and petrology is given using another unit text, entitled 'Earth Materials', and also using the bulk of the <u>home kit</u> (Fig. 8) which consists of a McArthur petrological microscope especially designed for the course, 25 rock specimens and 23 thin sections, 7 minerals, 7 fossils and other items including an acetate peel kit and materials for demonstrating aspects of structural geology. It is impossible to read the 'Earth Materials' text satisfactorily without having specimens to hand and the microscope set up, for throughout students have to complete tables summarising the properties of the specimens and thin sections. During the eleven weeks' duration of the Geology course, students meet part time tutorial staff at local study centres to discuss problems encountered during their studies. Students gain experience of field work during a week's summer school, which is at present based at the Department of Earth Sciences at the University of Leeds. The programme alternates between field and laboratory sessions, each laboratory session providing the opportunity for students to go over the field work they have done the previous day, or to revise any

Block Z (See Map 2)

Q.Z1 Which lithological unit rests unconformably on older strata? (Pencil out A, B, C, D, E, F or G)

Q.Z2 In which direction does the unit identified in Q.Z1 overstep?

KEY A : north
B : south
C : east
D : west
'd' : don't know

Q.Z3 What is the approximate angle of discordance of the unconformity in a north-south direction?

KEY A : 0°
B : 4°
C : 8°
D : 12°
E : 16°
'd' : don't know

Q.Z4 What is the approximate angle of discordance of the unconformity in an east-west direction?

KEY A : 0°
B : 4°
C : 8°
D : 12°
E : 16°

Q.Z5 Which of the following statements is correct?

KEY A : Only the beds above the unconformity V upstream.
B : All the beds V downstream.
C : The beds below the unconformity V upstream.
D : All the beds V u[illegible].

Q.Z6 What is the minimum thickness of the beds above the unconformity?

KEY A : 100 feet E : 500 feet
B : 200 feet F : 600 feet
C : 300 feet G : 700 feet
D : 400 feet

In comment row 2 of. Block Z indicate, by pencilling out the appropriate cell from the key below, how enjoyable were the questions in Blocks X, Y and Z in the sense that you experienced pleasure in doing them.

KEY a : very enjoyable
b : fairly enjoyable
c : not very enjoyable
d : not at all enjoyable

Likewise, in comment row 3, say how difficult these same questions were.

KEY a : very difficult
b : fairly difficult
c : not very difficult
d : not at all difficult

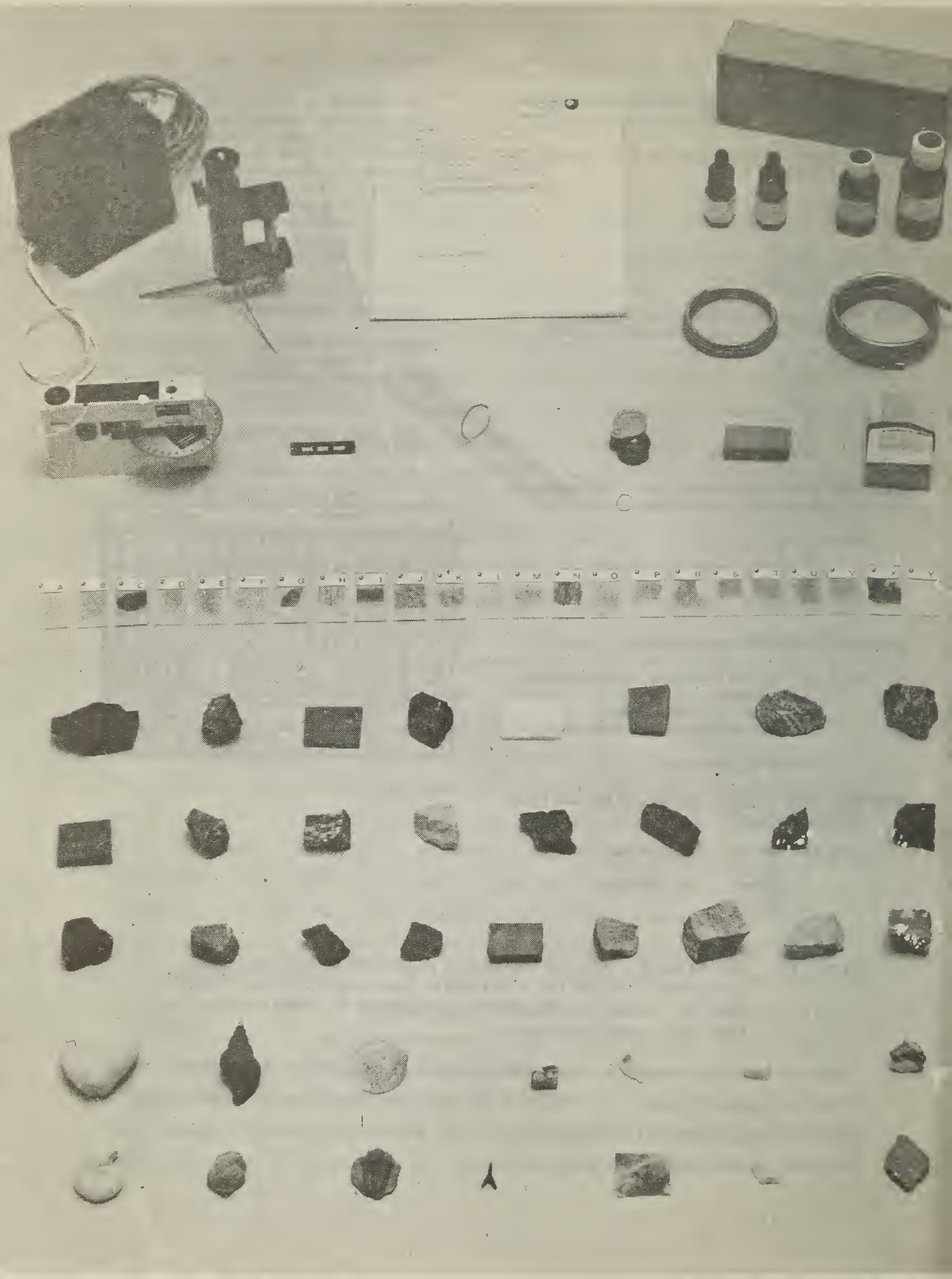
This block carries 15 per cent of the marks for this assignment.

Block Z cells for Q.Z1–Z6

	ANSWER							COMMENT 1			
1	A	B	C	D	E	F	G	a	b	c	d
2	A	B	C	D	E	F	G	a	b	c	d
3	A	B	C	D	E	F	G	a	b	c	d
4	A	B	C	D	E	F	G	a	b	c	d
5	A	B	C	D	E	F	G	a	b	c	d
6	A	B	C	D	E	F	G	a	b	c	d
7	A	B	C	D	E	F	G	a	b	c	d
	COMMENT 2							COMMENT 3			
	a	b	c	d	e	f	g	a	b	c	d

Fig. 7. An example of an objective test used in conjunction with a simple geological map used for a Computer Marked Assignment (CMA) for the Geology course.

aspect of the course tnat they wish. A student summer school book forms a detailed guide to the field work they undertake, thus freeing tutors to deal with individual student problems as they arise.



At the end of each course, students sit a final examination, which carries equal weight with their continuous assessment grades. A summer school assessment is used to arbitrate on borderline pass-fail and pass-distinction cases.

Table 1 summarises the components already discussed which make up a course unit. Thirty four course units make up a credit course, and six credits (of which two must be at foundation level) are needed for a student to gain an ordinary B.A. degree, and eight credits (of which two must be of foundation level and at least two at third level or higher) to give an honours B.A. degree. Foundation courses are broad interdisciplinary courses available in the faculties of Humanities, Social Science, Maths, Sciences and Technology. The Earth Science component of the Foundation Course in Science deals with large scale geology, rather than 'pigeon hole' geology. Material is biased towards geophysics, providing the opportunity to teach physical concepts such as reflection and refraction, rigidity and magnetism in the context of their relevance to the study of the Earth. The title of the units are 'The Earth, its shape, internal structure and composition', 'The Earth's magnetic field', 'Major features of the Earth's surface', 'Continental movement, Sea-floor spreading and Plate Tectonics', 'Earth History 1', and 'Earth History 11'. Once students have successfully

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Fig. 8. The home kit for the Geology Course. Top left: McArthur petrological microscope, tripod and transformer; top centre: instructions and roll of acetate peel; top right: large sponge coils of solder, plasticene and sliced telephone directory used for experiments associated with structural geology; the bottles contain acetic and amyl acetate for making acetate peels with the acetate sheet. Lower half of photography: thin sections, rocks fossils and minerals. The kit is packaged in specially moulded polystyrene containers and loaned to students for the duration of the course.

TABLE 1 - Components of an average Course Unit in Earth Science

Component	Study time (hours)	Description
CORRESPONDENCE TEXT	10	Specially written and structured text, containing behavioural objectives, table of scientific terms, etc., and self assessment material integrated with home kit materials.
SET READING	1.0	Reading parts of 'set book', which in some cases may have been specially written for the course (e.g. 'Understanding the Earth', set for all Earth Science courses).
HOME PRACTICAL WORK		Collection of 25 rocks, 7 minerals, 23 thin sections and 6 fossils, a petrological microscope, acetate peel materials and demonstration materials for structural geology. The kit is constantly referred to in correspondence texts.
COMPUTER-MARKED TEST (Weekly)	1.0	Objective tests; answers given by pencilling out items on sheet read by computer.
TUTOR MARKED TEST (spread over several weeks)	4.0	Subjectively marked; essays, short-answer questions, accounts of experiments.
TV PROGRAMME	0.5	Demonstration of conceptually difficult items or laboratory demonstrations.
RADIO PROGRAMME	0.5	Teaching material, or material showing history or social relevance of science.
BROADCAST NOTES	-	Notes containing instructions on tasks which should have been completed before the broadcasts, and summaries of the programme.

completed one foundation course they may go on to level two courses, a number of which are available in the geology area (Table 2). Students must combine a one third credit course with a one sixth credit course to give an overall half credit. This system ensures that at least some interdisciplinary approach is maintained during second level studies.

TABLE 2 - A summary of second level geology courses

Course title	Credit rating	Content
GEOLOGY	1/3	The aims of this course are to train students to approach objectively the identification of minerals and rocks and understand their genesis; to interpret major structural and geomorphological features and be able to deduce the processes involved in their formation; and to understand the principles of stratigraphy and palaeontology. There will be considerable emphasis on practical work throughout the course, and the home experiment kit will include a petrographic microscope, thin sections of rocks and a collection of specimens.
THE EARTH'S PHYSICAL RESOURCES	1/3	In this course, attention will be focused on the occurrence, location, processing and utilization of natural resources, ranging from metallic ores through the mineral fuels, oil, coal, natural gas and fissile materials to materials used in construction and industrial processes such as building stone, road metals, cement, metallurgical fluxes and fertilizers. Another title for this course could be 'geology in the service of man'. /continued overleaf

GEOCHEMISTRY	1/6	In this short course, the main emphasis will be on the methods by which geochemists select and analyse accessible Earth materials, the relationships between the chemical composition and the structure of rocks and minerals, the chemical aspects of the Earth's structural evolution, geochemical reactions and cycles, and the practical applications of geochemistry.
GEOPHYSICS	1/6	In this course, selected topics will be examined to illustrate the contribution of physics to our knowledge of the Earth. The emphasis will be on basic physics as applied to the Earth, rather than on the use of physical techniques to extend geological study.
ENVIRONMENT	1/6	This short interdisciplinary course will show how physical and biological processes influence the distribution of organisms and geomorphological or sedimentological features of natural environments. Particular attention will be given to coastal, river, lake and glacial environments, as they are well represented in the British Isles. The course is also intended to stimulate appreciation of the environment through the greater understanding of processes occurring in it, with a view to reconciling exploitation with preservation.

In this short article it is difficult to cover adequately all aspects of the Open University teaching system, but, one filal aspect that must be mentioned is the evaluation system. Feedback of all kinds reaches the course team (the team that has prepared all the course

materials). The assessment system is one kind of feedback, the summer schools another, the part-time tutors yet another. In addition, the reaction of academics in other departments is sought concerning the courses before they actually reach students, as they are evaluated before they are finally printed. In addition much time is spent in trying to isolate conceptually difficult parts of the course, and those parts of the course which have been badly taught. In the case of the Geology course this was accomplished by sending a specially designed questionnaire and log sheet to a randomly selected sample of students. Collation of the answers received provided a very rapid feedback and has enabled the course team to give a certain amount of guidance to tutors in the first year of the courses' operation. The evaluation of the course is now continuing with an in depth study of students understanding of some of the key concepts introduced in the course. In this way we hope that the Open University will live up to its name in <u>every</u> sense of the word, having an open admissions policy requiring no formal qualifications, open as to teaching methods, open as to new ideas, and above all being open to criticism.

Received January 1973

The first event of the year was the Annual General Meeting for 1971, held on the 6th of January, and followed by a showing of members' slides.

There have been five lecture meetings during the year; a sixth was postponed due to the emergency regulations imposed during the national power cut in February. The meetings were: January, Dr. R. G. Bromley on 'The Dryas'; February, postponed; March, Mr. P. G. Cambridge on 'Fossils of the Norwich Crag'; April, joint meeting with the Norwich Astronomical Society, I. O. Evans on 'The Earth - this surprising world'; October, Dr. R. G. West on 'A state of confusion in Norfolk Pleistocene stratigraphy'; November, Dr. F. J. Vine on 'Geology of the Deep Ocean Floor'.

The Committee has met three times, on the 11th April, 28th September and 23rd November.

At the Annual General Meeting I indicated that I did not wish to continue as Secretary after the end of 1972, but remarked that this should not be taken as reflecting any change in my attitude to the Society. Its Secretary, whoever he may be, quite naturally exerts some influence over the direction of the Society, so a periodic change is desirable to prevent too much bias one way or another. In my tenure of office the bias has been towards the museum and the lecture programme has been somewhat influenced by my personal tastes. The Society is now, I believe, ready for an expansion in membership, and some changes in emphasis, and I am confident that Dr. C. J. Aslin will as Secretary provide this. The last two meetings, held in the Castle schoolroom, have been so well attended that better accommodation is required; the four remaining meetings of the Winter programme are to be held at U.E.A., which offers better facilities.

I hope members will actively support the new Secretary and Committee under the new arrangements.

December 1972 Brian McWilliams

CONTENTS

The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may apply for election to the Society. For further details write to the Secretary: Dr. C. J. Aslin, The University Library, University of East Anglia, NORWICH NOR 88C.

Copies of this Bulletin may be obtained, 60p (post free), from the Secretary at the address given above; it is issued free to members.

Also available, at 75p (post free), is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

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BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 24

CONTENTS INCLUDE:

BULLETIN of the GEOLOGICAL SOCIETY OF NORFOLK 1
No. 24 September 1973
Editor: R. S. Joby
116 Gowing Road, NORWICH NOR 40M

EDITORIAL

The autumn edition sees the publication of two papers of great interest based on local fieldwork. Eaton caves provided the basis for interdisciplinary work by Messrs. Hornby, Goff and Goldsmith, while Dr. Randall throws new light on the Suffolk coast. There is also a report on a field meeting at Sheringham held last summer. Much independent fieldwork is being done quietly around East Anglia by a growing body of interested amateurs and professionals. When any worthwhile work has been completed, it is well worth writing it up for publication, and brevity need not be a drawback; in fact having a series of articles of varying length helps an editor.

Bulletin No. 25 will be issued in April 1974. Contributions should be sent to me as soon as possible, and no later than December 31, 1973.

Will contributors please note that manuscripts are acceptable in legible handwriting, although typewritten copy is preferred. In either case it would be a great help if details of capitalisation, underlining, punctuation, etc., in the headings and references (particularly) could conform strictly to those used in the Bulletin. Otherwise publication may be delayed.

Illustrations intended for reproduction without re-drawing should be executed in thin, dense, black ink line. Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations should, before reproduction, fit into an area of 225 mm by 175 mm; full use should be made of the second (horizontal) dimension, which corresponds to the width of print on the page, but the first (vertical) dimension is an upper limit only. All measurements in metric units, please. R.J.S.

Bull. geol. Soc. Norfolk, 24, 3 - 14 (September 1973)

EATON CHALK PIT - SITE OF SPECIAL SCIENTIFIC INTEREST

R. J. HORNBY*, J. G. GOLDSMITH/ and J. C. GOFF[x]

What is an SSSI?

Only a small fraction of all the land showing important natural features is, or ever can be, protected by means of nature reserves. There is therefore, a need to protect areas which are not established as nature reserves but which are nevertheless of interest on account of their flora, fauna, geology or physiographical features. In order to help prevent such areas from being unwittingly damaged or destroyed by development, the Nature Conservancy designates Sites of Special Scientific Interest (SSSIs) and lists them in schedules covering each local planning authority area. These schedules are distributed to the planning authorities and to many other bodies whose activities might in any way threaten the listed sites. SSSIs are carefully selected in order to safeguard localities for rare species or communities, and they include the whole range of semi-natural habitat types. Other sites are scheduled not so much to safeguard a valuable habitat for wildlife but to help ensure that exposures of particular geological significance continue to be available for scientific investigation. The protection of geological SSSIs, which are often quite small in area, usually operates through the planning authority who consult the Nature Conservancy in the event of development proposals likely to affect the site.

Eaton Chalk Pit is one such site. The designation of the northern side of the pit as an SSSI in October 1968 was based primarily on the status of the site as the type locality for the Eaton Chalk.

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x Owl's Hatch, SALHOUSE.

History of the Pit

It has not been possible to determine the date when chalk was first mined at Eaton, but the pit was known to have approximately its present dimensions at the turn of the century, and as all the chalk was dug by hand it indicates an origin probably in the early part of the nineteenth century. The chalk was used for the manufacture of lime and virtually all of it would have been roasted in kilns on the site. Two such lime kilns are known to have been in operation in the pit. The smallest, and oldest, of these still survives in reasonable condition to this day, but the other one, which was of German design and was constructed in 1889, has been filled in. The kilns were kept burning continuously and it is reputed that the only time they went out during the long operational life of the pit was in the flood of 1911. The fires were not finally extinguished until 1936 when the business closed down.

The chalk, which was mined solely with picks, was carried to the kilns along an often precarious system of planks, using heavy wooden wheelbarrows. The roasted chalk was subsequently carried manually up a flight of steps from the kilns for loading onto carts. It was sold by the cart-load or 'chaldron', which was just less than a ton.

Although the pit itself covers approximately 1 hectare, the normal method of operation during this century, and probably for much of the last century, was by digging a series of tunnels. There are believed to have been at least eight of these tunnels radiating outwards from the pit; three of them running east-wards under Donkey Lane and the remainder running northwards or westwards. The chalk was mined from tunnels in order to avoid the problem of disposal of the overlying sand and gravel. Some of the tunnels were of considerable size, reputedly large enough to take a double-decker bus! They remained open until 1944 when the army sealed them off. The army's attempt to block the entrances by blowing them up with explosives

proved utterly abortive, but the job was completed by bulldozing material over the entrances from the top.

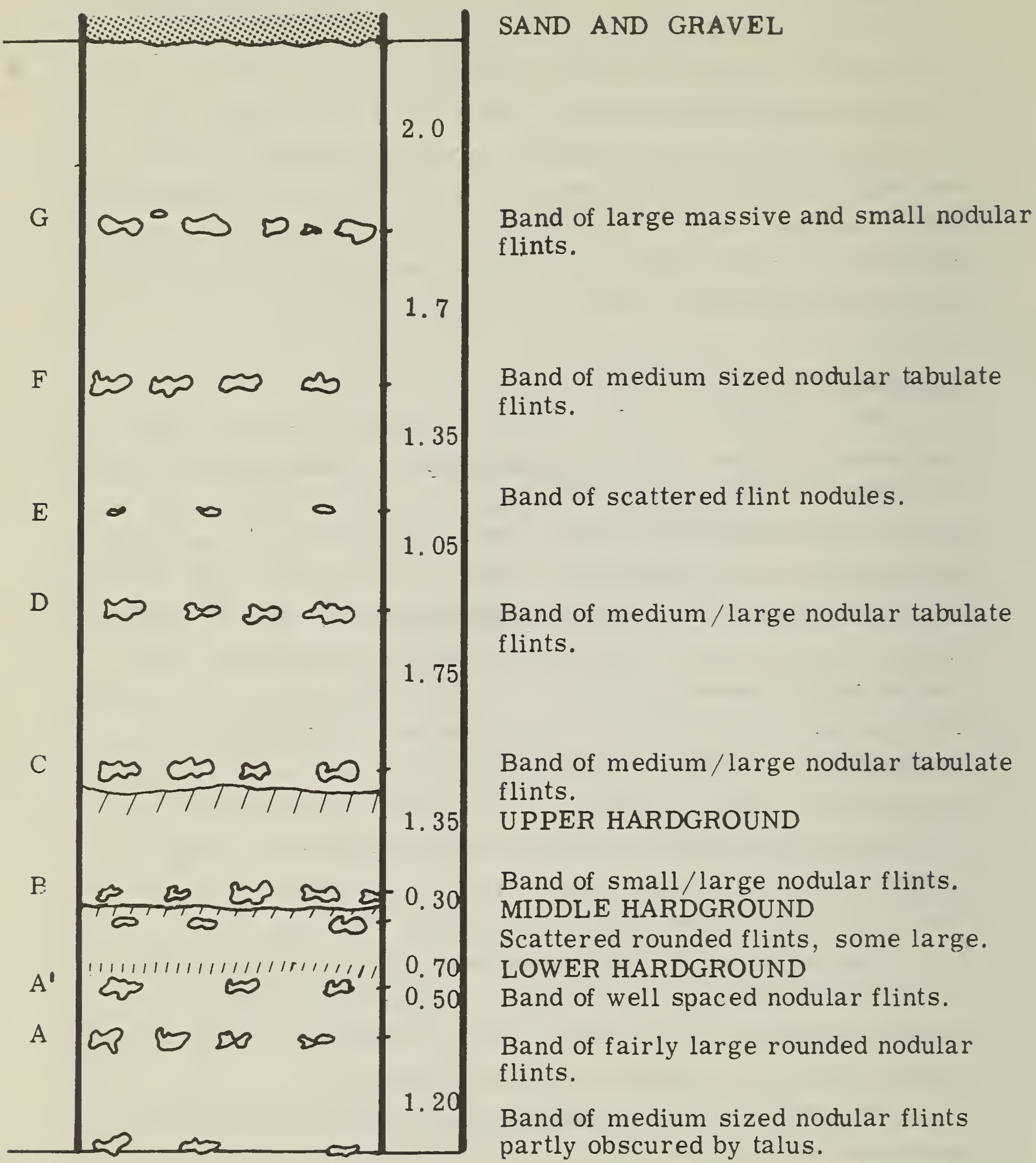
All but one of the tunnel entrances remained permanently sealed off but during the harsh winter and floods of 1947 part of the cliff face fell away, re-exposing a hole which formed a joint entrance to two separate tunnels. Although well concealed by vegetation, these tunnels were accessible to both geologists and bats until March 1969 when they were again blocked by material bulldozed into the pit from above.

Geology (by J. C. GOFF)

Eaton Chalk is the second lowest of the six sub-divisions of the zone of *Belemnitella mucronata* adopted by Peake and Hancock (1961, p.314). The tunnels at Eaton Chalk Pit provide the only permanent exposure of Eaton Chalk at present available. It is also the second deepest exposure in the *B mucronata* zone in the Norwich area. No overlaps of the section with exposures known to be in the lower part of the Weybourne Chalk have yet been proved. Part of the section may correspond to a temporary exposure seen during foundation work for the University of East Anglia. The total thickness of the section, from the top of the chalk above the tunnel entrance to the lowest part inside the cave is 12 metres. The details of the section are shown in Fig. 1.

The letters in the section refer to flint bands described by Dr. M. R. Leeder. The fossils that he collected from the section, now in Norwich Castle Museum, are numbered according to this system.

The beds of hard chalk (hardgrounds) represent periodic shallowing of the sea when bottom currents were stronger and greater amounts of terrestrial sediment was carried into the sea. These hardgrounds are typically associated with a rich fossil fauna. The upper hardground contains glauconitic material and is separated from below



The letters in the left hand column are those used by Dr. Leeder to locate fossils. The middle column gives the distances between the flint bands, which total 12.0 metres.

FIG. 1 THE SECTION THROUGH THE CHALK AT EATON

by a prominent bedding plane with a hard calcitic top. The hardground increases in hardness towards the top. The middle hardground consists of an irregular 7 cm band of hard yellow chalk. The lower one consists of yellow chalk of variable hardness.

The details of the fauna of the section are as follows:-

Brachiopods:

Cretirhynchia lentiformis Woodward, var α Leeder
Cretirhynchia cf. *norvicensis* Pettitt
Neolithyrina obesa Sahni
Carneithyris spp.
Kingena lima (Defrance)

Neoliothyrina obesa and the Carneithyrid brachiopods are only known to occur above flint band E. They do not occur in exposed lower horizons in the *B. mucronata* zone.

Kingena lima is characteristic of flint bands E - F. Its occurrence here is significant stratigraphically - the species being restricted to well defined horizons in the zone.

Cretirhynchia lentiformis occurs throughout the section and is especially common near flint bands E - F and B - C. A large sample of this species from Eaton was measured and the average length/width ratio was found to be 1.05. All other known species of *Cretirhynchia* from the zone have length/width ratios of less than 1. Dr. Leeder defines the range of the variant as being from the Lower Eaton Chalk to the Middle Weybourne Chalk.

Cephalopods:

Belemnitella occurs throughout the section and is particularly common between flint bands B - C in the upper hardground. The majority of the specimens from Eaton are waisted forms referable to *Belemnitella langei* with some tapering forms referable to variants of *Belemnitella mucronata*. This indicates a horizon high in the Eaton Chalk.

Echinoids:

Small bun-shaped Galerites occur in the upper hardground along with a conical form of Echinocorys. Echinocorys is common near flint band A1, and a flattish oval form occurs near flint band B. There are several specimens of Galeola in the Norwich Castle Museum from Eaton. However these specimens may have been collected from long tunnels which extend from the caves towards the North East. Thus they may have been derived from a younger horizon than is seen in the present section (the dip of the chalk brings younger beds to the surface in an easterly direction). The specimens are the types originally described by Brighton in 1939.

Other fossil groups:

Sponges and clumps of Serpulids occur in the upper hardground. Of the bivalves, Pycnodonte vesiculare and Spondylus spp. are sparingly common.

Bats

Although the geological significance of the chalk was the main reason for the area being designated an SSSI, the presence of hibernating bats in the tunnels had also influenced the decision. One of us (JGG), together with J. Buckley, began visiting the tunnels at Eaton in 1964 in order to examine the bats. Only one species, Daubenton's bats (Myotis daubentonii) was ever recorded there, but their presence in the tunnels had been known by at least five other people during the preceding ten years. The greatest number of individual bats recorded in these tunnels was 30, but single figures were very much more normal.

In view of the decline in the populations of most species of British bats (Stebbings 1965, 1967), and the acute shortage of winter roosting caves in East Anglia, the presence of bats in the tunnels at Eaton was regarded as a highly significant factor. The majority of lime workings which at one time had offered roosting sites for bats have long been blocked off or have caved in and many other

possible sites are subject to human disturbance. It has been shown by Stebbings (1966) that bats disturbed during hibernation have a greatly reduced chance of surviving the winter owing to the depletion of their food reserves by unseasonal activity.

Present Condition of the Pit

The topography of the chalk pit has been subject to considerable modification at various stages during its history. Large volumes of overburden were shifted about while the chalk was being mined, and later the near-vertical walls of the pit were reduced to almost a 1 in 1 gradient by the activities of the army during the war. In the early 1960s the main floor of the pit was raised about 6 metres when it was used as a dump for large quantities of unwanted soil and builders' rubble. The result of these activities was that all the chalk faces were obscured apart from the small surviving exposure by the entrance to the only accessible tunnels.

Trees and scrub of various ages have become established in the pit, creating a useful habitat for wildlife and an unofficial adventure playground for local children. The trees are mainly Birch, Ash, Oak and Sycamore, while Hawthorn, Blackthorn, Privet and Elder are also abundant. The flora of the site includes such species as Hoary Mullein (*Verbascum pulverulentum*), Kidney Vetch (*Anthyllis vulneraria*), Spotted Hawkweed (*Hieracium maculatum*) and Hybrid Medick (*Medicago falcata* x *sativa*). The soil and rubble dumped in the floor of the pit has also been colonised by an interesting mixture of vegetation which includes much Fennel (*Foeniculum vulgare*).

The Re-opening of the Tunnels

As has already been mentioned, the last of the tunnels were blocked off in March 1969, after which only about 1 metre at the top of the chalk was accessible. The SSSI was therefore hardly justifying its status and it was clear that the possibility of re-opening one of the tunnels would

have to be investigated. A further factor in the decision to go ahead with the re-opening of a tunnel was that R. E. Stebbings was at the time seeking suitable sites in East Anglia for the furtherance of his studies into the ecology of bats. He particularly wanted to find caves in which human access could be controlled so that disturbance to the bats could be kept to a minimum. It was decided that, if at all possible, an attempt should be made to re-open the tunnels which had been sealed off in 1969. The reasons for this choice were: (a) two tunnels could be opened by clearing only one entrance, (b) one of us had known them while they were open and knew in which direction the digging would have to proceed, and (c) there was no doubt about the suitability of the tunnels as a hibernation roost for bats and it would therefore be of great interest to study their re-colonisation once they were re-opened.

The owner was initially somewhat reluctant to sanction the re-opening of the tunnels, partly on account of an inherent antipathy towards bats and aversion to seeing more of them around his garden. After listening to the case for the conservation of bats and their roosting sites, however, he generously agreed that the work could go ahead. Unfortunately it was not possible to use any form of mechanical digger because of the difficulty of access, and there was therefore no alternative but to call on parties of volunteers armed with spades, shovels and mattocks.

The first work party assembled on 2nd October 1971, and was composed of enthusiastic members of the Norfolk Young Naturalists. This group removed much of the rank vegetation and managed to enlarge the area of exposed chalk from about 2m x 1.3m to 5m x 2m. Further enlargements to the chalk face were accomplished over the next few months by parties from the University of East Anglia Conservation Corps, the Coastal Ecology Research Station of the Nature Conservancy and occasional lunchtime sessions by two of the authors and other interested persons. The job became extremely

slow because of the necessity to lift the material from the steadily growing hole and carry it almost nine metres to the edge of the spoil heap.

The final privilege of breaking through to the tunnel went to a party of Norfolk Young Naturalists led by J.C.G. on 4th August 1972. Altogether a total of nearly 250 man-hours had been spent on the task, and a depth of about five metres from the top of the chalk to the tunnel had been exposed. The entrance was subsequently enlarged, mainly by shovelling soil downwards into the tunnel from the inside, and later the second tunnel, which was much the larger of the two, was broken into.

Once the tunnels had been re-opened, detailed plans were made for erecting grilles over the entrances. Advice on materials and the spacing of the bars was obtained from R. E. Stebbings who has had considerable experience of erecting bat grilles. The grille was constructed and fixed in position by Hubbard Bros. Limited of Norwich on 1st September 1972, at a cost of £86. It consists of a 5m diameter semicircular iron frame, with horizontal bars 17 cm apart and vertical rods 23 cm apart. The frame was positioned so as to completely cover the entrances to both caves. It was welded onto supports 23 cm apart hammered well into the ground and into the chalk. It has a hinged central gate 60 cm square which is kept padlocked. This grille allows bats to pass freely into and out of the tunnels and also permits ready exchange of air which is an important factor for the hibernating bats. The whole structure is extremely rigid and remains unscathed after more than one abortive attempt to damage it or break into the tunnel.

<u>Mapping of the Tunnels</u>

The lay-out of the tunnels is shown in Fig. 2. This map is the end-product of several hours of surveying by P. and J. Buckley. The major problems in surveying arose from the overall shape of the tunnel system, the darkness,

the irregular floors and different levels, and in some parts the confined working space. The methods used were broadly to take bearings and measurements from a series of fixed points which consisted of candles stuck to the tops of ranging poles. The usual army prismatic compass proved to be very difficult to use in the darkness, but a Suunto compass was found to be more suitable when illuminated by torch-light.

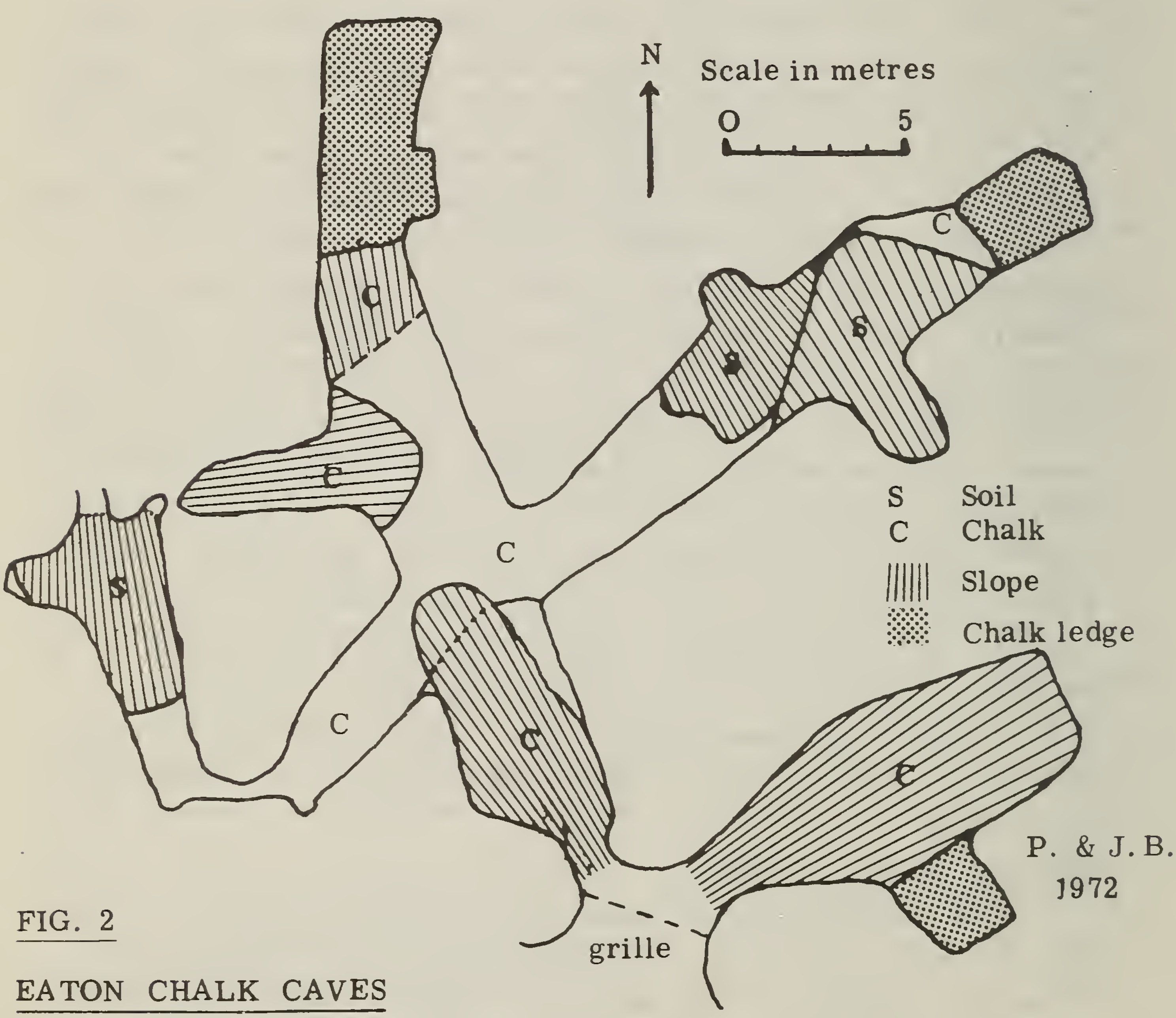


FIG. 2

EATON CHALK CAVES

Future Access Arrangements

It has been agreed with the owner that access to the tunnels should be controlled by the Nature Conservancy, but they are available for serious scientific investigation. Because of the risk of disturbance to roosting bats and interference with the studies being conducted into the recolonisation of the tunnels by bats, no permits for entry will normally be granted during the winter (1st September to 31st March). During this period only the minimum number of visits will be made to the caves, to record the numbers, species and distribution of bats roosting within them. All the observations on the bats will be made by R. E. Stebbings or persons authorised by him. During the summer months geologists may visit the caves by arrangement with the Nature Conservancy, 60, Bracondale, Norwich, NOR 58B, to whom all enquiries should be made.

Acknowledgements

We would like to express our gratitude to the owner of the chalk pit, Mr. P. H. Pointer, for his helpful co-operation during the re-opening of the tunnels and for his continuing generosity in allowing his property to be used for research purposes. We would also like to thank Mr. J. Woodrow for valuable information about the history of the chalk pit. This information was supplemented by documentary evidence made available by Norwich City Library and Norwich Castle Museum. Finally we would like to say a word of thanks to all the people whose combined efforts resulted in the re-opening of the tunnels.

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SHINGLE STREET, SUFFOLK: AN ANALYSIS OF A GEOMORPHIC CYCLE

R. E. RANDALL*

Abstract

The resultant of shingle movement in the littoral zone at Shingle Street is to the north in contrast with much of the east coast of England. This anomaly is associated with the growth of North Weir Point, and water movement in the Ore estuary. Growth of Shingle Street shingle spit is traced over a period of 70 years and related to the external controlling factors of material supply, waves, currents and protection. Suggestions are made for student use of this or similar areas to gain further understanding of coastal morphology.

Introduction

In recent years a growing number of schools, field-study centres, colleges of education and universities have included the measurement of physical processes in the field within their environmental science curricula. This activity is to be encouraged since it is one of the most effective ways to lead both students and teachers away from the misconceptions that derive from some of the older textbooks in geology and physical geography. Generalizations and theory based on insufficient field data have resulted in gross oversimplification of the real-world situation. Dury (1963) has pointed out several problems associated with the river in geographical teaching but the coast too has suffered similarly. This is a great pity, because the coast is not only accessible to many students, it is also a very rapidly changing dynamic system which well repays repeated observation and mensuration even at

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short intervals.

The principal aims of this paper are to describe one such rapidly changing system, the shingle beach at Shingle Street, and to recommend further work that students could carry out at this or other coastal locations.

Shingle Street is a part of Bawdsey Parish, on the coast of Suffolk, England. It is situated on the west bank of the estuary of the River Ore, opposite North Weir Point, the distal end of Orford Ness.

The history of Shingle Street, the River Ore and North Weir Point are closely bound together and must be regarded as a single entity when attempting to understand the physiographic development of the district. The area of prime interest is an accumulation of shingle east of the sea wall in the northern part of the hamlet. It is composed of a series of apposition banks enclosing several lagoons. Projecting northwards and making an acute angle with the mainland is a shingle spit behind which an arm of the sea is situated (Fig. 1).

Although several writers e.g. Carr (1965, 1969, 1970, 1972), Carr and Baker (1968), Kidson and Carr (1959), Kidson, Carr and Smith (1958), Steers (1926) have previously dealt with the total locality, including Shingle Street, much of their work has focussed on Orford Ness; but Cobb (1956, 1956/7) specifically investigated Shingle Street.

It is widely recognized that the general direction of long-shore drift of beach material along the east coast of England is southward, as is immediately visible from the morphology of Orford Ness itself, Holderness and Landguard Point. However it has become increasingly obvious as investigation continues that this is not true for all the coast (Williams 1956). Shingle Street is an example of one of these anomalies, where growth is in a northerly direction up the estuary of the River Ore. Protection afforded by North Weir Point from the dominant north-easterly winds may in part explain this (see page 29)

but wave-direction theories are rarely sufficient to explain such phenomena totally. Robinson (1955) found that on the south coast of England residual water movements helped to explain such features.

Pre-1893 History - The Cycle

Early maps and charts show that in the Middle Ages Shingle Street had a cliffed coast (Norden 1966) but since that time there has been continuous change. This has involved the cyclic increase and wane of North Weir Point with concomitant effects at Shingle Street. At the commencement of a cycle North Weir Point lies in a northerly position and there is a series of irregularly shaped islets and banks to the south of it. This situation is followed by a period of consolidation during which the Ness extends southwards incorporating the islets and banks until it is level with the southern extremity of the hamlet. At this stage it becomes unstable and is broken by a severe storm so that the Ness reverts to its northerly position and the islets and banks reappear. During this cycle Shingle Street becomes gradually more protected and then suddenly is exposed once more.

An example of this cycle can be traced on successive maps (in Norden, op. cit.) by Kirby (1736), Hoskisson (1783) and Carey (1807). For the nineteenth century a more accurate picture can be gained from the Admiralty Charts of 1811, 1847, 1892 and 1894 and the Ordnance Survey maps of 1838 and 1879. This cycle culminated with the storm of November 18th-20th, 1893, when the last kilometre of the Ness was driven landward, allowing the sea to beat on Shingle Street unhampered for the first time in a century. The Ordnance Survey 25" map of 1904 provides the first recorded occurrence of the shingle beyond high water mark at Shingle Street: this probably dates from the 1893 storm. At this time the sea most likely reached as far as the main ridge, while the Ore flowed out to sea via the sea-arm and the Lagoons (Fig.1).

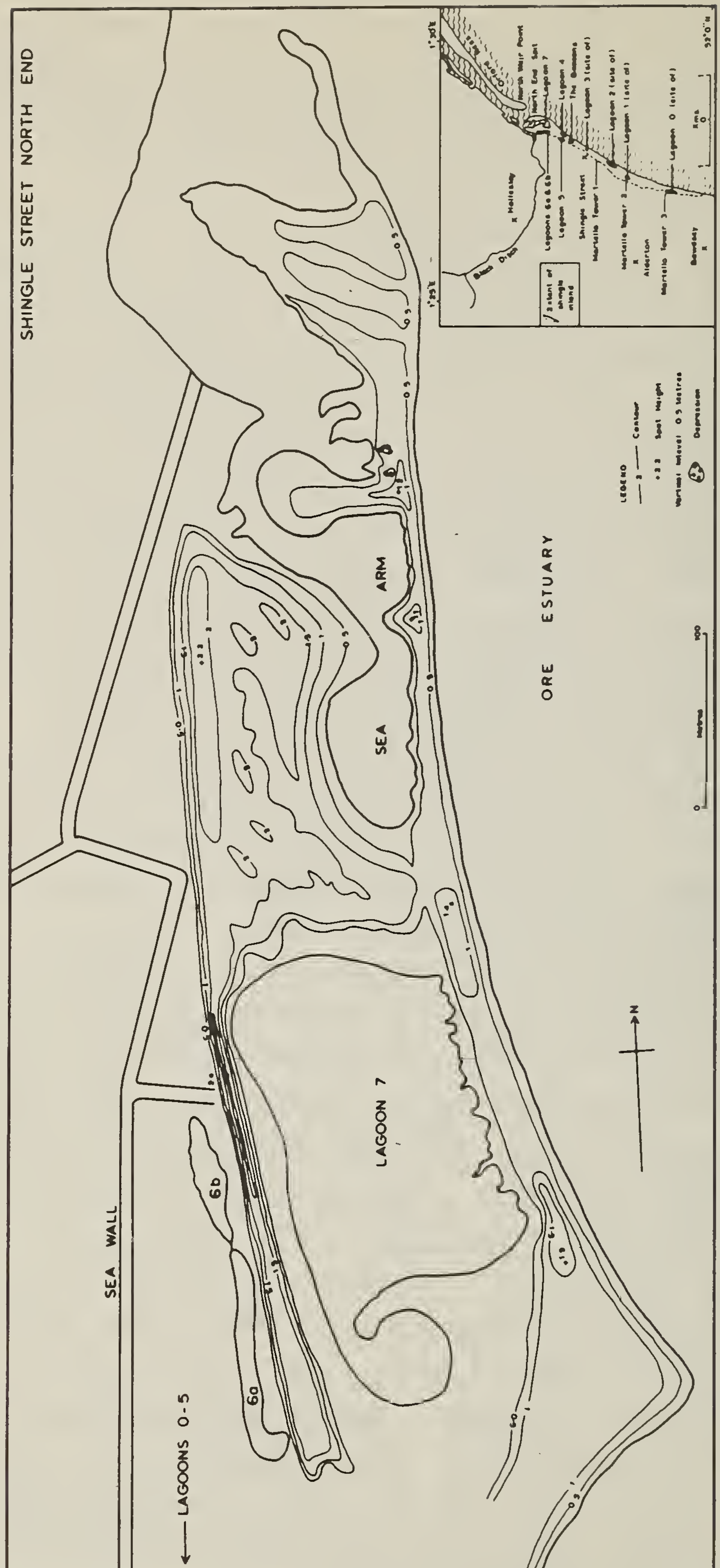

Fig. 1 Location and topography of Shingle Street

The Present Cycle

The twentieth-century stages of the cycle at Shingle Street have been recorded in considerable detail by surveys and aerial photographs since 1942. Unfortunately there is little accurate evidence for the period between 1904 and 1942, except an Ordnance Survey revision of the southern portion of the 25" map in 1924. Fig. 1 (inset) shows the series of lagoons numbered 0 - 7 from the south by Cobb (1956) which diversify the beach at Shingle Street. These lagoons fall into three categories. Lagoons 0 - 3 are tidal (by seepage) though separated from the open sea by a shingle bank. They are all floored with alluvium and were almost certainly part of the bed of the Ore. They are visible in embryonic form on the 1904 Ordnance Survey map and were permanent features by 1924. During the post-war period these lagoons began to be infilled and they were greatly reduced in size by landward movement of material between 1948-1953. As a result of the 1953 storm surge these lagoons virtually disappeared and now are seen only as depressions in the shingle. Lagoon 4 is a larger example of the same type and has been slower to fill in. Lagoons 5, 6a and 6b are much further inland than the others, and were probably originally man-made. Lagoon 5 appears on the 1904 Ordnance map and may well be a borrow-pit from which material was taken to construct the sea-wall. (Lagoons in a similar position farther south by Martello Tower 2 have sides and floors of laid septarian blocks.) Lagoons 6a and 6b are situated in an area where shingle was worked during World War II and neither were in evidence on the 1904 Ordnance Survey Map. These lagoons do not have an alluvial floor above the London Clay (Fig. 2).

Lagoon 7, the largest and northernmost of the lagoons is also the most interesting physiographically. This lagoon was not in existence in 1904 when both it, and the sea-arm immediately to the north, were a part of the Ore estuary. Although there is no documentary evidence,

local residents say that North End Spit had begun to form by 1926, causing an embryonic Lagoon 7. At this time North Weir Point was considerably north of its present position: thus growth of the spit and northward movement of material was not initiated under protection of Orford Ness, though the latter may have had some effect on wave incidence, especially since the dominant winds on this coast are from the north-east.

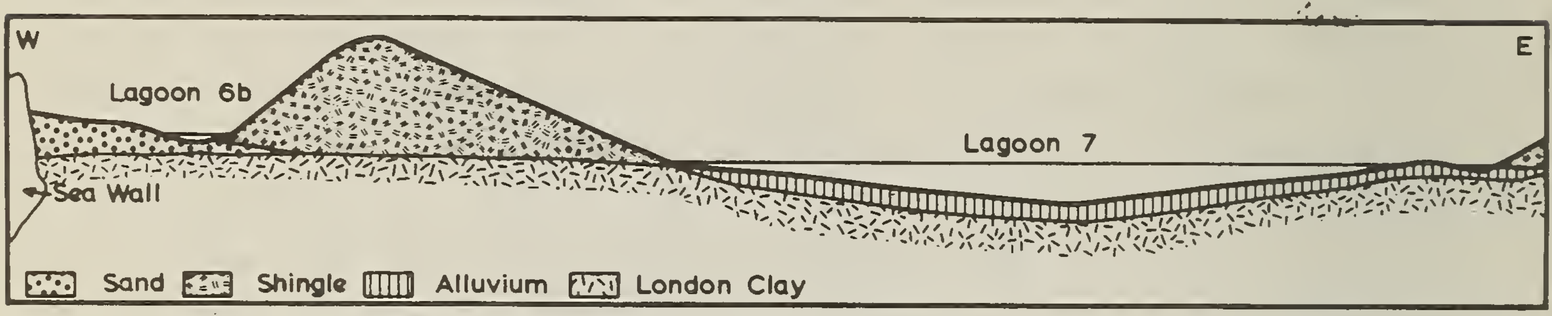

Fig. 2 Geological cross-section of Shingle Street through Lagoons 6b and 7

The development of the sea-arm and Lagoon 7 can be traced from a succession of maps (Appendix 1) and aerial photographs (Appendix 2) which have been employed in drafting figures 3 - 6 inclusive. The following principal components of change can be detected:-

1. Removal of shingle by man 1939-1945, giving the irregular coastline morphology visible on Figure 3, and the 1945 air photograph (Fig. 4).
2. Development of recurved hooks on the sea-arm by 1945 (Fig. 4).
3. Reversion to a regular coastline on the west bank of the River Ore (Fig. 5).
4. Very rapid northward growth and accretion of the sea-arm 1945-1951 (Table 1).
5. Considerable westward movement of shingle following the 'Great Tide' of 1953. The development of a storm-ridge on the east side of Lagoon 7; 'fulls' smoothed over and 'lows'

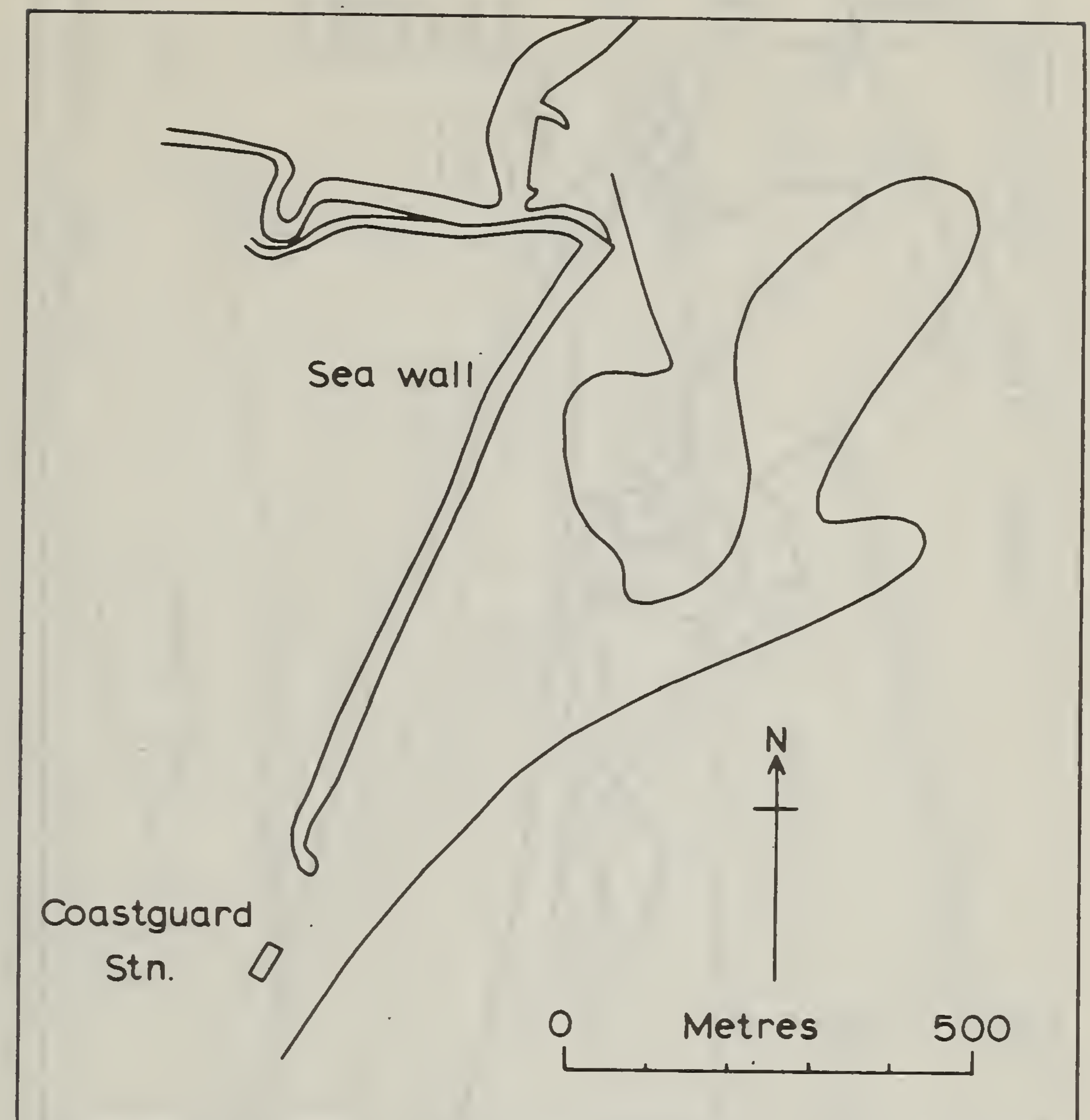

Fig. 3 Manuscript map of Shingle Street, by Suffolk Rivers Catchment Board, 1942

filled in (photographs of 4th February, 1953) Fig. 4. A reduction in growth-rate of the sea-arm (Table 1), corresponding to that of North Weir Point (Carr 1965, p.120).

6. Thickening of sea-fringe to a maximum in 1955 (Table 2) and the formation of a 'ness' opposite Lagoon 7 (Cobb 1956/7, Plate 1). (The ness may be an indication of the way Shingle Street receives some of its material (Carr 1965, p.125)

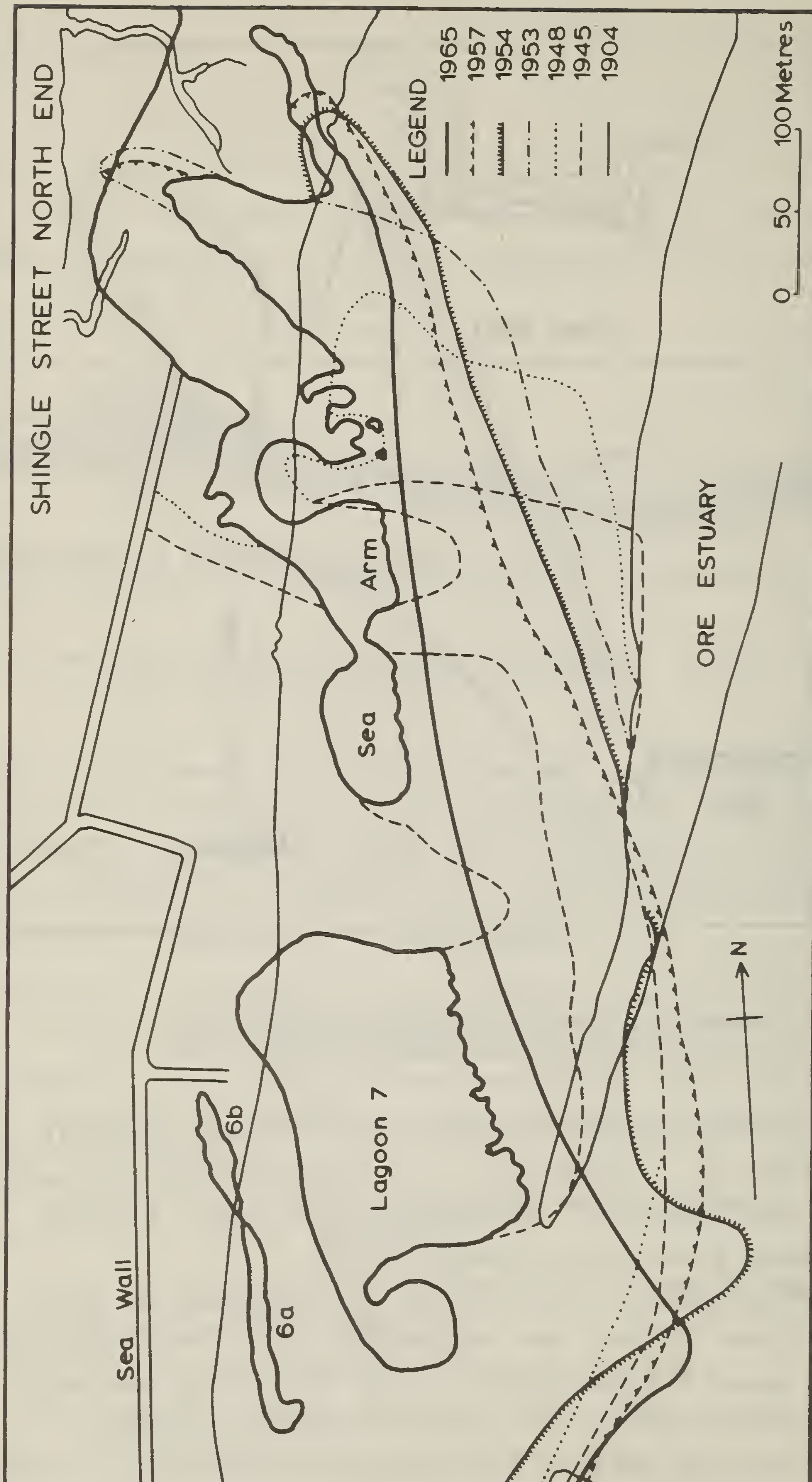

Fig. 4 Composite map showing the changing coast-lines at Shingle Street during the twentieth century

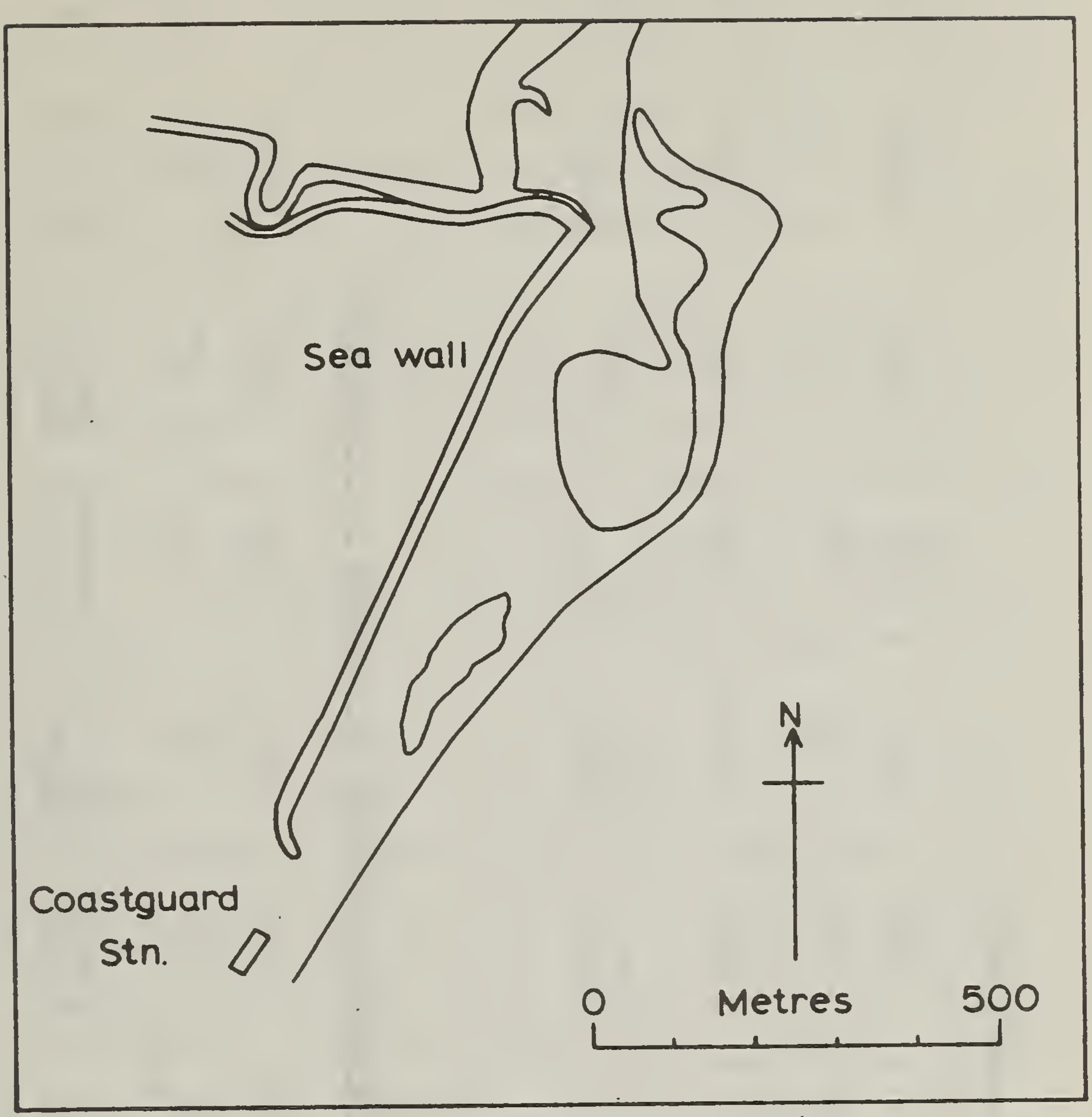

Fig. 5 Manuscript map of Shingle Street, by Norfolk and Suffolk Rivers Catchment Board, 1946

but the full complexities of the shingle movement are still unresolved (Carr 1972).

7. Erosion of the eastern side of the sea-ridge from 1956 (Fig. 4). It was from this date that the northern part of Shingle Street became protected by Orford Ness. The growth of the latter caused a constriction of the Ore channel and hence erosion of the west bank, see Myrick and Leopold (1963).

TABLE 1

NORTHWARD ELONGATION OF SEA-RIDGE, 1945-1970

Date	1945	1948	1951	1954	1956	1961	1965	1968	1970
Increase (metres)	-	129	50	51	14	26	20	4	2
Length (metres)	0	129	179	230	244	270	290	294	296
Source	Air photo	Air photo	Air photo	Air photo	Cobb (1956)	Air photo	Author	Air photo	Author

TABLE 2

WIDTH CHANGES OF SEA-RIDGE AT SOUTHWESTERN CORNER OF LAGOON 7, 1945-1970

Date	1945	1948	1952	1955	1961	1965	1968	1970
Width (metres)	60	85	86	91	46	33	38	31
Source	Air photo	Air photo	Air photo	Cobb (1956)	Air photo	Author	Air photo	Author

8. Continued erosion of the sea-ridge and slow northward elongation of the sea-arm to 1961 (Fig. 6). A bodily westward movement of the whole ridge caused a narrowing of the Lagoon 7 outlet, which was finally sealed in 1962. Shingle Street North End is now fully protected by North Weir Point.
9. Survey of 1965 (Fig.1) by author. Highest point of sea-ridge at Shingle Street coincident with 1904 location of distal point of Orford Ness. Reduction in size of Lagoon 7 caused by shingle infill; a further spread of shingle over the original Lagoon 7 outlet; a decrease in area of recurved spits as sea-ridge moves further west.

   The latest survey of the area was made by the author in October 1970. This survey and aerial photographs of March 1968 show that most of the trends experienced earlier were continuing. North Weir Point was growing further southwestwards and the sea-ridge at Shingle Street was consequently encroaching upon Lagoon 7 as the swash and ebb channels of the River Ore were displaced. At its greatest extent the north shore of the latter was 175m in length; in 1970 it was barely 78m. The sea-arm had silted up further and more shingle had been thrown between it and Lagoon 7. These were joined in 1961 but by 1970 were 90m apart. Little material appeared to be reaching North End Spit: it was 296m long, fractionally more than in 1965, but the northern portion was underwater at spring tides and the distal point had been turned westwards.

Shingle Movement

The source of the material at Shingle Street and the sequence of its movement are intriguing facets of the

Fig. 6 Vertical air photograph of Shingle Street in October, 1961. (V-AK 93/95. Courtesy of J. K. St Joseph, Cambridge University)

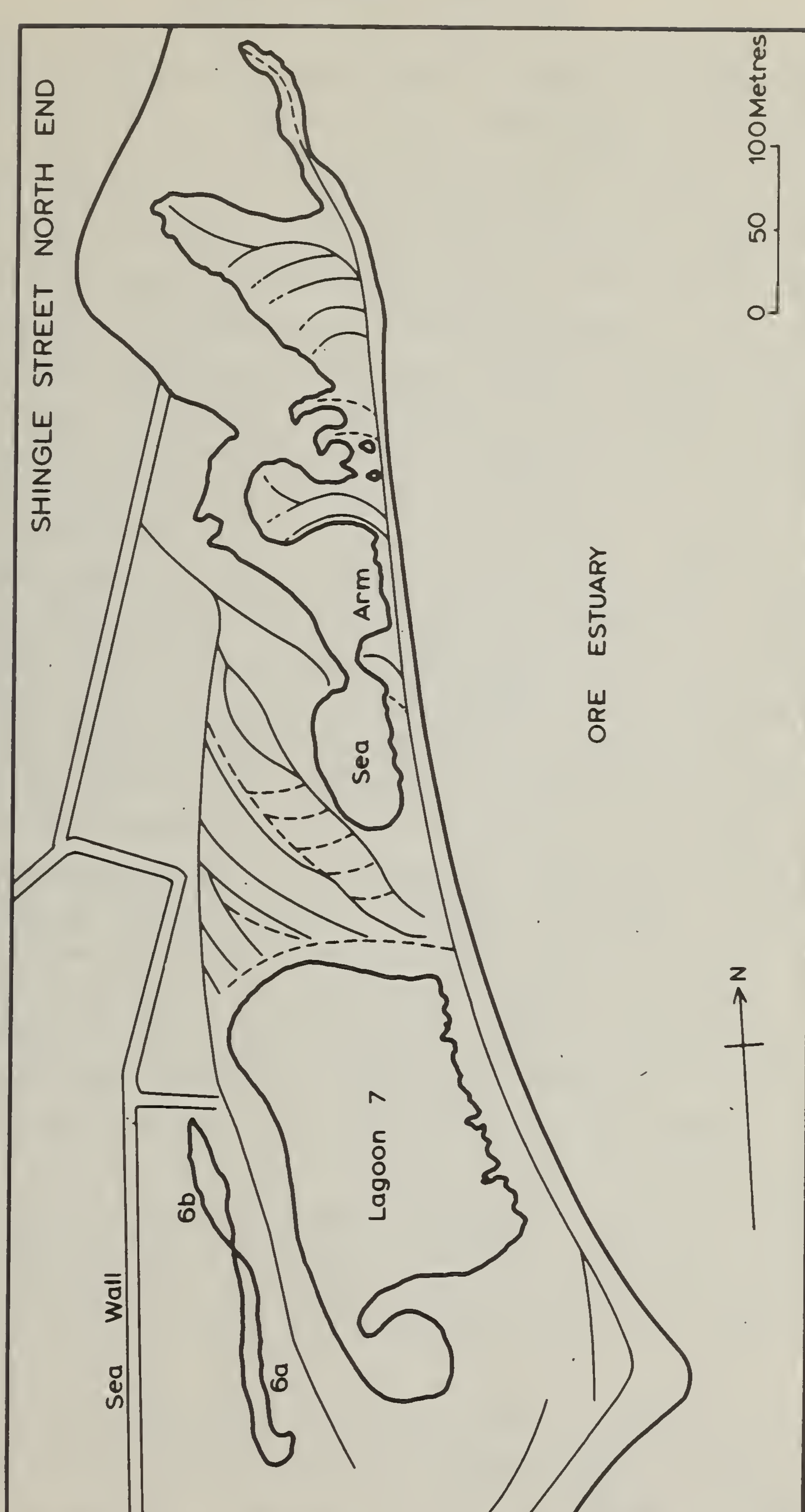

Fig. 7 The direction of Shingle ridges at Shingle Street

study. Figure 7 shows the position of the fulls and lows in the area of Shingle Street under observation. There are two series of ridges, an older group to the west of Lagoon 7, bent southwards, and a newer one to the east, bent northwards. The greater part of the shingle is flint, which initially came from the Chalk, though it has reached Shingle Street via wave action on the glacial deposits of the coast. It has also been suggested that offshore banks and shoals might produce some beach material(Kidson 1963). The most likely immediate source of material is the southward moving shingle of North Weir Point. Work in the Ore estuary by Kidson and others(Kidson and Carr 1959, Kidson et al. 1958), using shingle marked with radioactive tracers, shows that, at the present day, movement of shingle in the off-shore zone is virtually non-existent so that material from banks and shoals could be discounted as a source of supply. Experiments showed that if material drifted south to the North Shingle Bank (immediately south of North Weir Point) it was unable to cross the estuary to the Shingle Street side but merely progressed slowly towards the river channel and contributed to the southward progression of North Weir Point. However, other material which drifted to the South Shingle Bank further south and further seaward, crossed the estuary via the shallow river bar, and reached Shingle Street south-west of Lagoon 7. This line of movement can always be seen at low tide by a line of broken water and occasionally shingle appears as arcuate islets.

For a spit to elongate successfully two conditions must be fulfilled. There must be a plentiful supply of material at the same time as conditions are favourable for its movement, and, since this coincidence is unpredictable, conditions may exist for a considerable period without movement occurring. This could be why events at Shingle Street appear to be sequential and cyclic, yet irregular over short periods.

Shoals and banks on the sea floor prevent the free approach of waves. There are two cordons of banks off the Suffolk shore, the inner of which, the Aldeburgh Napes and the Shipwash, are only covered by about 2 metres of water at low tide and protrude as islets in places. Much closer inshore, landward of the 6 metre line, there is extensive development of shingle flats, nearly exposed at low tide. Even the main channel of the Ore estuary is only 2 metres deep. These flats are a marked barrier to large waves at low water thus limiting the size of waves able to attack Shingle Street and affecting the obliquity of their approach to the coastline.

Waves are important agents in moving beach material and they are controlled by the winds of the area, which come most frequently from south and west. It is from this direction also that most storms originate. Southwesterly winds are prevalent but not dominant. The greatest fetch is from the north-east quadrant, from the East Frisian Islands, off the North coast of Holland, a distance of only 420km. The fetch from all points to the north of this is ineffective because of the shielding influence of Orford Ness. Thus, even the dominant waves are not as great as might be expected. (It is interesting to note that south of Shingle Street where southerly drifting is resumed, the north-easterly dominance is much greater, there being a line of fetch to Norway.) Furthermore, the mass of shingle to the south of Hollesley Bay acts as a proctection against the south-easterly winds of 160km fetch. It seems therefore that the main northward movement of material in the Ore estuary is not at present due to normal longshore drifting, and waves only aid in the supply of suspended material.

Local currents are basically tidal. At Shingle Street the flood tide flows northwards to Slaughden, while water pours from the estuary and its tributaries in a southerly direction on the ebb. In fact water is still leaving

Orford Haven when the flood begins within the bay. The juxtaposition of various currents in this anomalous area produces conflicting wave systems.

Although even strong currents are unable to shift shingle alone, they play an important auxiliary part in moving shingle lifted into suspension by breaking waves (Steers 1953, p.16). Similarly backwash-motivated material may be affected. In the Ore estuary the current flow is strong, Carr (1965, p.120) suggests seven knots, and steady enough to have an important effect, especially since the northerly current occurs with a rising tide, lifting the same shingle several times and shifting it considerably.

It can be seen that the area of overall northward movement is limited to a small region within or near the estuary. The actual building of fulls is done by waves, generated by strong southerly winds but these occur too infrequently to be the main transporting agent; currents transport shingle lifted into suspension by waves.

Conclusions

It would appear that the physiographic development of Shingle Street during this century is as follows. Southward moving material on Orford Beach reaches North Weir Point and separates into two portions. That reaching the South Shingle Bank crosses the Ore by the estuary bar and accumulates between "The Beacons" and Lagoon 7. Some of this material continues to move south under the aegis of normal longshore drifting while the rest moves north under combined wave and current action within the estuary. Variations within the cycle can be explained in terms of supply of shingle. During the period from 1893 to 1920 little material crossed the bar and thus little action occurred. Between 1920 and 1953 a good supply of shingle enabled considerable accretion north of "The Beacons" and starvation of the beach to the south occurred. (Since the Ordnance Survey revision of 1924, HWMOT has moved over 150m

inland near the coastguard station.) Since 1953 a smaller amount of material has crossed the bar, and Shingle Street has become more protected. Thus, less material is available to move north; hence the narrowing of North End Spit. But at the same time a decrease in encroachment south of "The Beacons" has occurred since longshore drift continues with the material which is available. If earlier records are any guide, North Weir Point has a considerable distance to grow southwards before becoming unstable once more.

Further Research

It will be interesting to note what changes occur at Shingle Street when it is no longer at the mouth of the estuary but well inside it. School and college students could easily assist in this research. The following small projects might be carried out by visiting parties:

(i) measure the width of the sea-ridge at the south-western corner of Lagoon 7. This would add to the data in Table 2 and thus give some idea of the lateral shift of the Ore estuary.

(ii) measure the length and orientation of the north end of the sea-ridge. This would be a reliable way of assessing the amount of material moving northwards.

(iii) students visiting the area for a period of more than one tide could paint pebbles (with orange marine paint?), place them on the foreshore, and observe distance and direction of movement.

Although only one location has been described in this article, the investigation of archival evidence, followed by practical work on site, could be carried out for very many coastal features of the British Isles. Obviously lowland areas of accretion such as dunes or sand and shingle spits are much easier to work with then slowly changing sea cliffs and other erosional features. In some places however, erosion causes much local concern and could profitably be measured. The major significance of this study is the day-to-day dynamism that is revealed in coastal geomorphology, a process and time scale often overlooked in teaching in the field.

Acknowledgements

The author wishes to acknowledge the pioneer work done in this area by R. T. Cobb, and help received from F. J. Bingley. Thanks are also due to the Ministry of Housing and Local Government, to Dr. J. K. St. Joseph, Cambridge University, for supplying relevant air photographs, and to D. M. H. Vulliamy for permission to carry out fieldwork on his property. Part of the fieldwork was supported by a grant from the Essex Education Authority.

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Williams, W. W. 1956 An east coast survey: some recent changes in the coast of East Anglia. Geogr. J. 122, 317-334.

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APPENDIX 1

CARTOGRAPHIC SOURCES

Date Published or Surveyed	Reference Number	Source
1811	101 (A1)	Hydrographic Office
1838	48 N.E.(1", 1st edition)	Ordnance Survey
1847	2052 (A1)	Hydrographic Office
1872-8	2052 (B2)	Hydrographic Office
1879	90 (6" edition)	Ordnance Survey
1892	2052 (BIO)	Hydrographic Office
1894	2052 (B12)	Hydrographic Office
1904	77.16 (25", 2nd edition, revised 1902)	Ordnance Survey
1924	Revision of parts of sheet 77	Ordnance Survey
1942	Manuscript map	East Suffolk Rivers Catchment Board
1946	Manuscript map	Norfolk and Suffolk Rivers Board

APPENDIX 2

PHOTOGRAPHIC SOURCES

Date Taken	Reference Number	Source
16.10.1945	4435 RS 106G/U.K./ 929	R.A.F.
11.7.1947	S 56-64	J.K.St.Joseph, Cambridge Univ.
24.6.1949	CQ 066-069	" " "
2.8.1951	HC 046-048	" " "
21.3.1952	Various	R.A.F.
4.2.1953	V 0049-0051	Ministry of Housing and Local Government
23.6.1954	OF 53-54	J.K.St.Joseph, Cambridge Univ.
3.3.1955	0180 F 22 58/R.A.F./ 1672	R.A.F.
6.6.1956	SW 15-18	J.K.St.Joseph, Cambridge Univ.
16.6.1958	WM 49-53	" " "
17.6.1959	YJ 50-54	" " "
15.6.1961	V-X 86	" " "
28.10.1961	V-AK 93-95	" " "
1.6.1963	AHB 86	" " "
10.6.1965	AKZ 55-61	" " "
26.4.1968	AUG 50-52	" " "

Bull. geol. Soc. Norfolk, 24, 37 - 44 (September 1973)

ENVIRONMENTAL GEOLOGY OF SHERINGHAM

(Report of a Field Meeting held 16 September 1972)

B. M. FUNNELL*

Environmental geology is concerned with the effects of geology and geological processes on human activities. The Sheringham district provides several examples of such effects, which were visited by the Society in the summer of 1972 and are recorded here, although it is emphasised that this is not a systematic account of the environmental geology of Sheringham. The principal locations are shown in Fig. 1.

Mineral Workings

The Drayton Stone Pits Ltd. operates a gravel working (TG 168415) in the Briton's Lane Gravels - a deposit of coarse gravels and sands, probably laid down at the northern margin of the Lowestoft glacial advance of the Anglian glaciation. Most of the gravel is composed of flint with scattered erratics of ganister, dolerite and decomposed acid igneous and metamorphic rocks. The bedding indicates deposition by water flowing in a generally north-ward direction. Now the deposit is terminated northwards by steep slopes fretted by periglacial valleys (Fig. 2). Occasional lenses of glacial till are intercalated in the upper part of the gravels towards the south of the pit. In an east - west direction the Briton's Lane Gravels (Sand and Gravel) are quite continuous as far as Pretty Corner and beyond (Fig. 3).

In places lenses of marl or reconstituted Chalk form part of the irregular basement of glacial till of the mainly Cromer Advance (Loam and Clay) on which the Briton's Lane Gravels rest. Previously lime workings and a lime kiln

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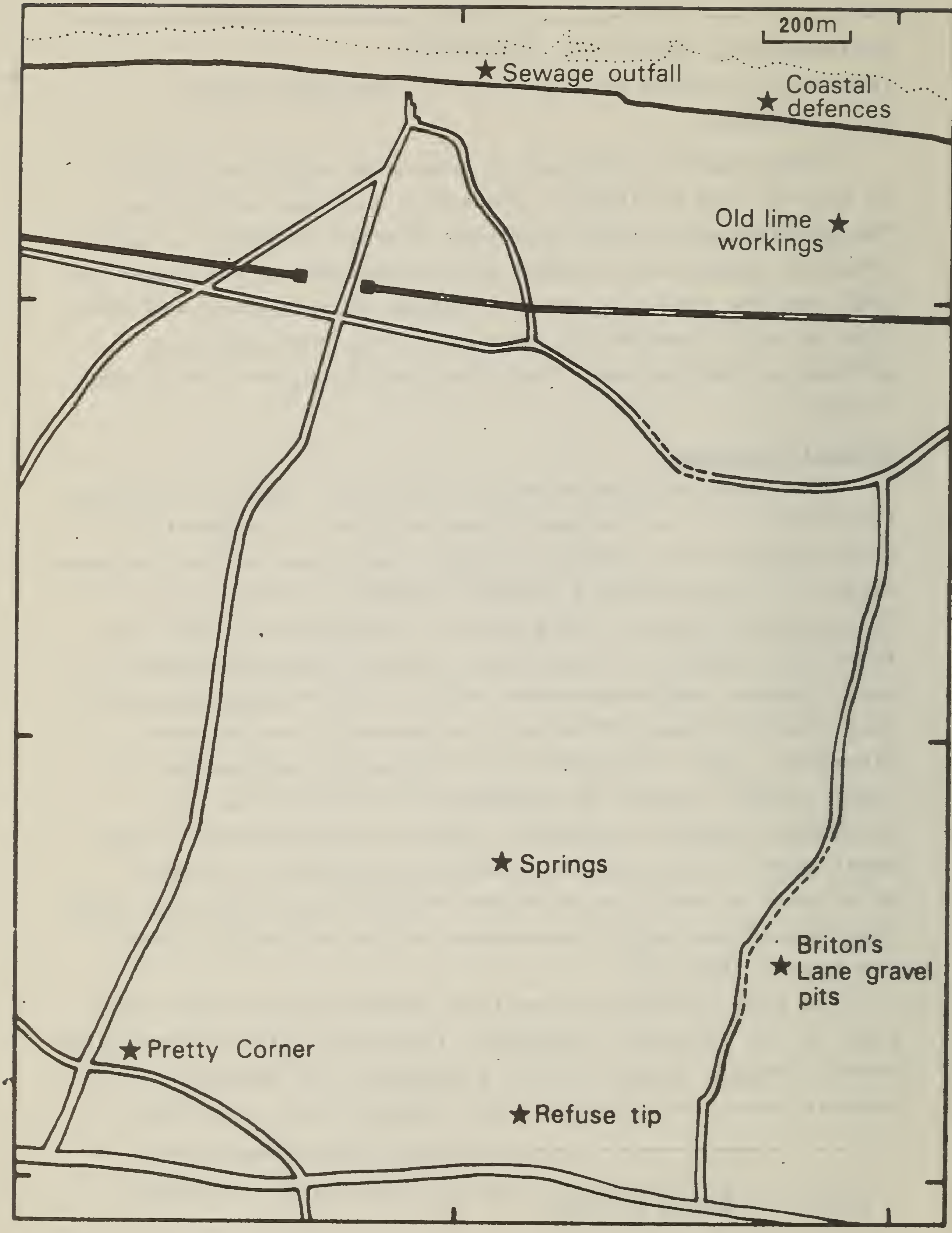

Fig. 1 Key to locations

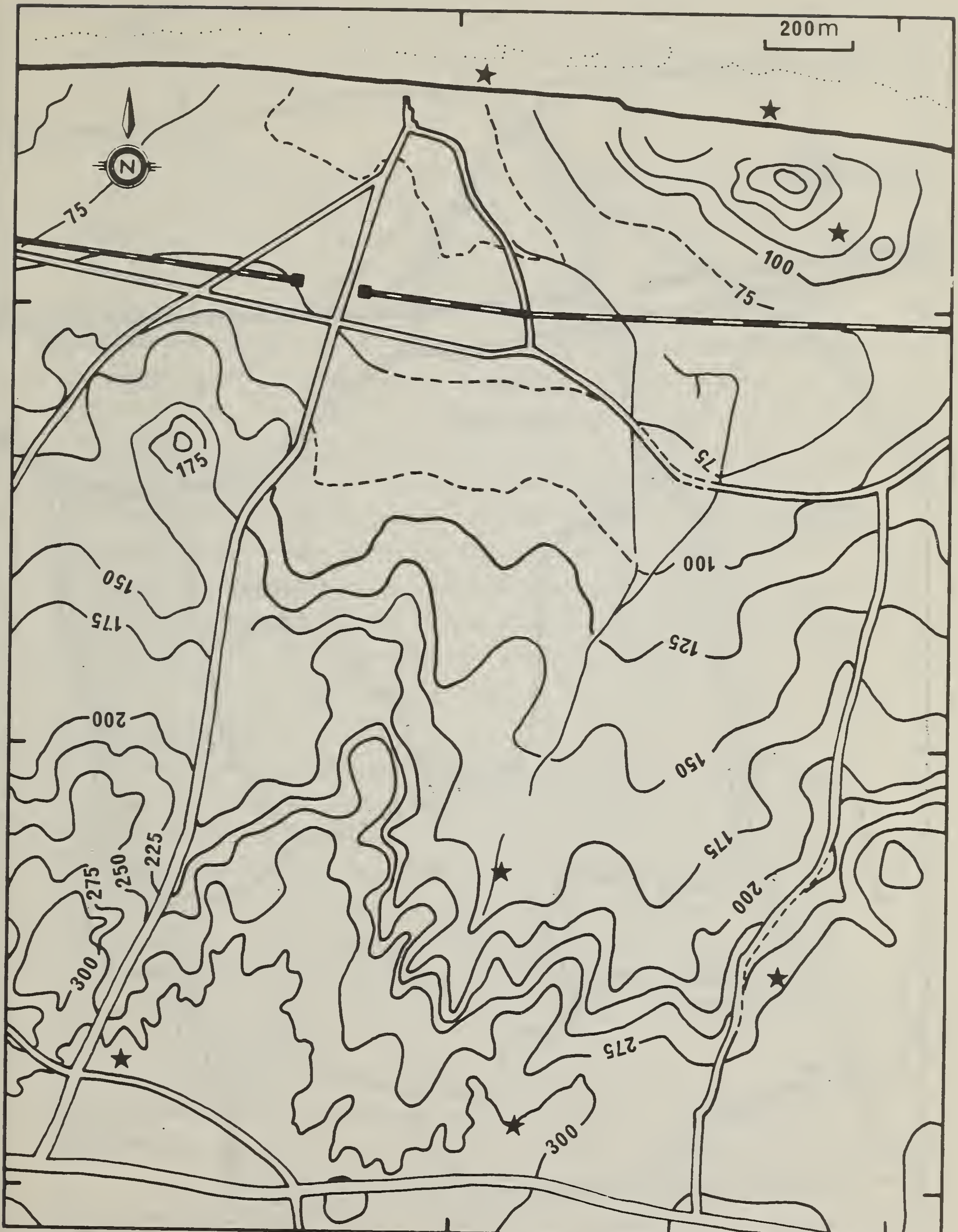

Fig. 2 Topography

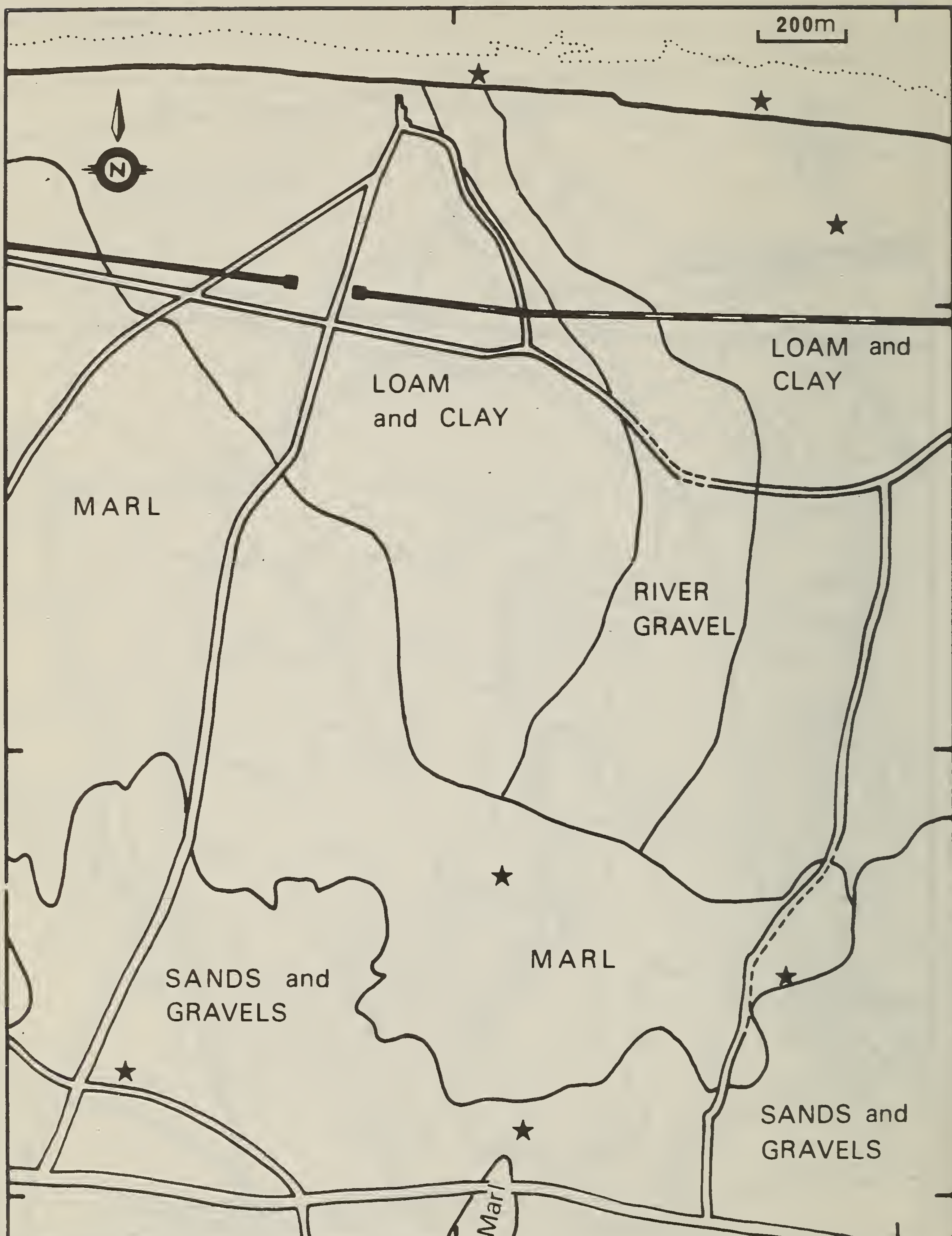

Fig. 3 Geological deposits

were operated in such a lens on the lower ground just east (TG 169432) of Beeston Hill.

Water Supply

Water percolating into the porous Briton's Lane Gravels from rainfall accumulates as groundwater held up by the underlying glacial till complex, (Loam and Clay, with Marl lenses). Where the periglacial valleys on the north side of the ridge cut down to the contact between the gravels and the glacial tills, springs fed by this groundwater occur. Clearly in the past, higher rates of flow give rise to a significant river, and associated train of gravel (River Gravel), which reaches the sea close to the present centre of Sheringham. Historically these springs (TG 160418) provided the original public water supply for Sheringham, although bore-holes sunk by the Sheringham Waterworks Company in 1818 and 1924 penetrate the glacial till and draw water from the underlying Chalk formation. Further development of the groundwater from the gravels is currently being considered.

Waste Disposal

Domestic refuse was deposited during the 1950's at the head of one of the periglacial valleys (TG 162412). In such circumstances the mainly bacterial effluent from domestic refuse is effectively and rapidly filtered by the underlying porous sands and represents no threat to the groundwater supplies in the gravel deposits generally. Furthermore the restoration of the site by levelling concordantly with the flat top of the ridge is straightforward and inconspicuous.

Sewage disposal is less a problem of geology than of coastal currents, although the reliability and economy with which a sewer pipe can be built a sufficient distance out to sea will be influenced by the geology of the seafloor. Near Sheringham the top of the Chalk formation is almost precisely at sea-level beneath the glacial deposits, and

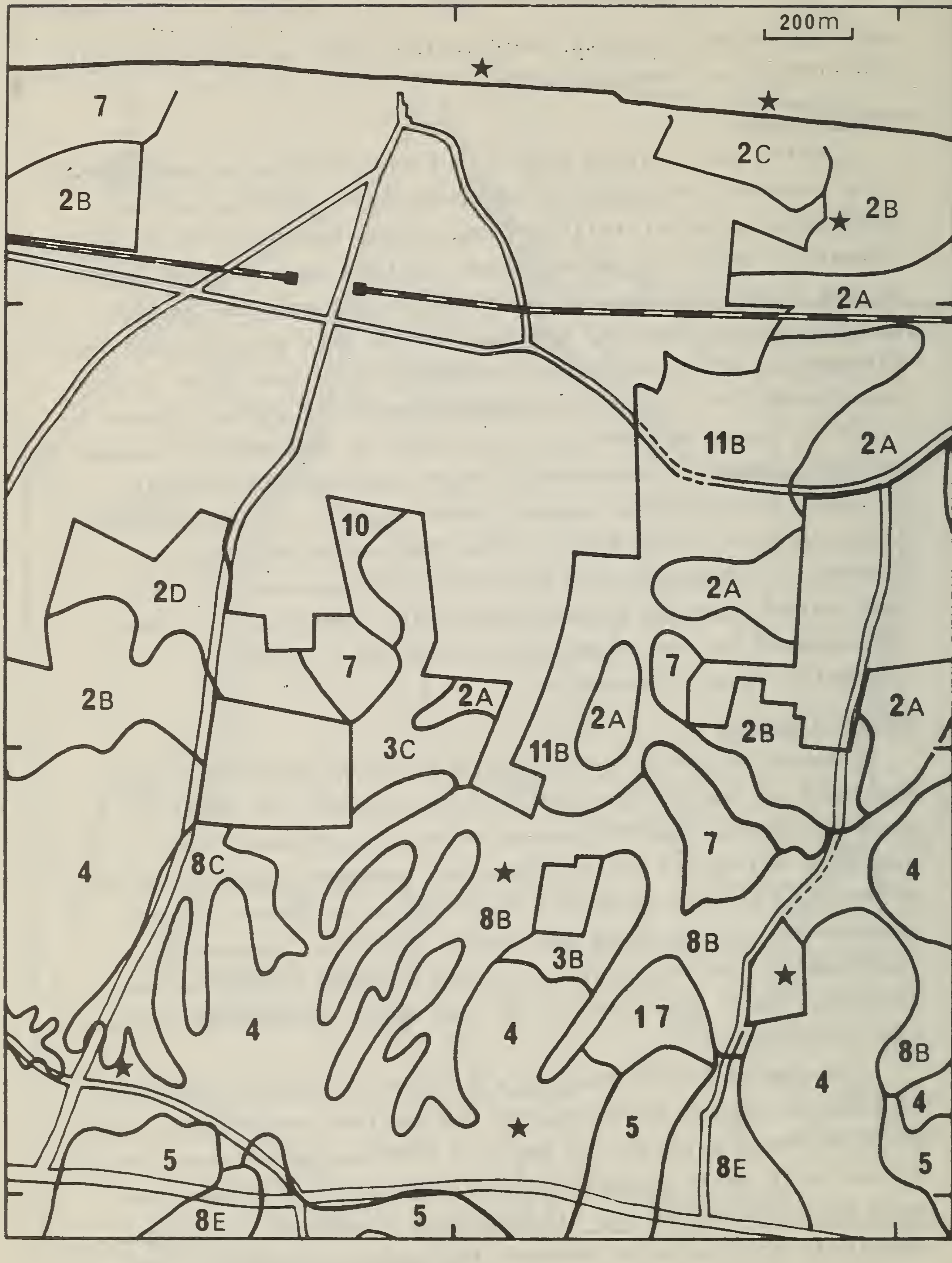

Fig. 4 Soils (for explanation see text)

forms a platform covered by sand and shingle extending offshore. The present outfall extends some distance offshore from the beach near the centre of Sheringham (TG 161435).

Soils

The geology of the Sheringham district has a strong influence on the local soils (Fig. 4).

On the upper part of the so-called Cromer Ridge, here consisting of the flat or very gently sloping top of the Briton's Lane Gravels, Freckenham Series brown earths and Red Lodge Series podzols are developed (4). In the periglacial valleys fretting the steep north-facing slope of the ridge Sheringham Series brown earths are developed on the 70 to 200 cm thick loamy colluvium, which overlies the gravel of the valley floors (8B and 8C). On the very gently sloping ground, which descends southwards from the flat crest of the ridge, Hall Series brown earths are developed on the probably aeolian loams which overlie the gravels in that direction (5).

The lower ground nearer the coast, where it is composed of the wetter loams and clays of the 'North Sea Drift' of the Cromer Advance, produces Weybourne Series gleyed brown earths (2A and 2B). Where the deposits are more sandy or gravelly as on Beeston Hill or adjacent to the northern face of the ridge, however, they give rise to Freckenham Series brown earths (2C, 2D, 3B, 3C and 7). On the other hand, elsewhere, particularly adjacent to the course of the former river, Gresham Series or Sustead Series groundwater gley soils develop on the aeolian loam or loamy colluvium overlying the 'North Sea Drift' (10 and 11B).

Coast Protection

The soft sediments of which the Sheringham cliffs are composed are very prone to slumping and erosion. Even where there is a protective seawall and promenade, the build-up of water pressure in the mixed layers and lenses

of glacial sand and clay, mainly of the Cromer glacial Advance, can lead to slumping even of previously grassed slopes. Eastward particularly, beyond the protection of the seawall, rapid erosion has occurred at the foot of the cliff, followed by slumping of the clayey deposits in the lower part of the cliff, and slipping of the sands and gravels forming for instance the top of Beeston Hill. In order to prevent erosion of the foot of the cliff the seawall has now been built eastward to a distance of over 1 km (80 m in the 1930's, 390 m in 1960, and 220 m in 1968) from the centre of Sheringham to approximately TG 169434. The face of the cliff behind the seawall is however still unstable and liable to collapse, and will remain so for some time to come.

Road Construction

The Holway Road down into Sheringham used to descend from Pretty Corner (TG 152413), itself on top of the flat-topped ridge at about 90 m (300 ft.) O.D. following the route of one of the larger periglacial valleys. The new road was constructed around 1970, using modern earth moving equipment that has made it possible to cut across the spurs separating the different heads of the main valley, giving a straighter route. Pretty Corner is still an excellent point from which to investigate the steep-sided heads of these periglacial valleys, probably formed in times of permanently frozen subsoil with high summer surface run-off. Because the ravine-like sides are composed of porous coarse gravel and sand, they have retained their steepness to the present day.

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116 Gowing Road, NORWICH NOR 40M

EDITORIAL

Our President, Brian McWilliams, gave us a stimulating and entertaining Presidential Address in the autumn, and gave me additional pleasure by having the manuscript of the address with him, so that it can be printed in this edition despite the earlier editorial deadline. In taking his survey to the middle of the 19th century, Brian leaves room for further contributions to this topic which I hope will be pursued before long.

Roland Randall contributes a further article in this edition, bringing his experience as an extra-mural tutor to our pages and providing further insights into the uses of geology in education.

Our other major item is a further contribution from the Soil Survey of England and Wales, this time on the geology of the Ely District, and as a bonus a new 'Map of the Geology of the Ely District'. Many thanks to the Survey and Richard Seale for permission to publish.

As a result of a decision taken at the Annual General Meeting it has been decided to print an additional single-topic Bulletin annually. These will update and eventually supersede the very popular 'Geology of Norfolk', which will soon be out of print for the second time. Brian Funnell's Bibliography of East Anglian Geology will also be appearing in the near future and will be invaluable in assisting researchers into local geology. His assistance in the production of the 'Bulletin' is likewise invaluable.

Bulletin No. 26 will be issued in September 1974. Contributions should be sent to me as soon as possible and no later than June 30, 1974.

Will contributors please note that manuscripts are acceptable in legible handwriting, although typewritten

copy is preferred. In either case it would be a great help if details of capitalisation, underlining, punctuation, etc., in the headings and references (particularly) could conform strictly to those used in the Bulletin. Otherwise publication may be delayed.

Illustrations intended for reproduction without redrawing should be executed in thin, dense, black ink line. Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations should, before reproduction, fit into an area of 225 mm by 175 mm; full use should be made of the second (horizontal) dimension, which corresponds to the width of print on the page, but the first (vertical) dimension is an upper limit only. All measurements in metric units, please.

R.S.J.

We apologise for the late production of the Spring Bulletin, through circumstances outside our control. It it expected that the Autumn bulletin will appear at its usual time during September.

B.M.F.

Bull. geol. Soc. Norfolk, 25, 3 - 14 (June 1974)

THE PLACE OF EARLY COLLECTORS IN THE DEVELOPMENT OF GEOLOGICAL STUDIES IN NORFOLK

(a summary of the Presidential Address for 1973 delivered October 25, 1973)

B. McWILLIAMS*

The First Collectors

The first collectors of geological material, in particular fossils, lived in Palaeolithic times and the association of collections of fossils with the remains of early man has been described from many parts of the world (Oakley 1965). Fossils were collected for a variety of reasons; personal decoration, ritual, religious, medical or even constructional purposes, as in the use of mammoth bones in dwellings by Upper Palaeolithic tribes of the Don Valley. In addition there is evidence for a regular trade in fossil (and recent) shells among the Upper Palaeolithic hunters of Europe.

Collections formed for the purpose of study are unlikely to have valid claims to such antiquity, though Aristotle (384 - 322 BC) may well have collected geological specimens as part of his natural history studies, as may have Pliny (23 - 79 AD) who published on mineral substances and gemstones in his later books. Subsequent authors relied on these two writers (Whitehead 1970) rather than on actual collection and observation, and the classical works were the standard texts in the scientific expansion following the invention of printing. Perhaps the real beginnings of collecting for study are seen when men like Leonardo da Vinci (1452 - 1519) used the methods of observation and experiment and so required specimens. At this time most collectors were merchants who sought to enhance their status, but they acquired natural objects as well as art works and classical relics. Geological material became included more

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in collections, particularly 'figures stones' as fossils were termed, until by the eighteenth century few educated men did not believe in the organic origin of fossils. John Ray (1628 - 1705) and Robert Hooke (1635 - 1703) were leading supporters of the theory of the organic origin of fossils (Bassett 1971).

Sir Thomas Browne (1605 - 1682) a Norfolk man by adoption, is perhaps the earliest recorded collector from this area - fossil bones from his collection went to the Royal Society and subsequently to the British Museum in 1781. Around such collections informal groups of interested men arose and these led to the establishment of scientific societies which had an important influence on the advancement of science; they provided a nucleus around which grew journals, museums and other institutions which provided an essential framework for development. The Royal Society often met in Gresham House and the Museum was catalogued in 1681 by Nehemiah Grew; it included some teeth of Rhinoceros antiquitatis ('Woolly Rhino') presented by the then Archbishop of Canterbury. John Woodward (1665 - 1928) had access to these collections, as 'Professor of Physick' in Gresham College, for his first major geological work (J. Woodward 1695), but also formed extensive collections of several thousand rocks, fossils and minerals in his own right. The organisation of such a large geological collection required careful documentation which led to the publication of detailed catalogues (J. Woodward 1729), and also the first exposition of 'keeping a Register of the Fossils as they are collected' (J. Woodward 1728) which gives advice that still holds good today.

Geological collectors and their collections can be assessed by the importance of the person who formed the collection, the geologists who used them, the state of geological knowledge at the time, and the social background that influenced whether the aim was to enhance the prestige of its owner or aid the advancement of knowledge. It is

in this light that I look at some early Norfolk collectors.

William Arderon

William Arderon FRS (1703 - 1767) has recently emerged as an important naturalist figure in the context of eighteenth century Norfolk through the availability of considerable manuscript material (Whalley 1971) which gives an insight into how observation and collecting were applied at this time. Arderon noted and drew fossils and a manuscript book of such drawings from 1749 - 1757 is in Norwich Castle Museum, together with two other manuscript volumes once held by F. Kitton, who first drew attention to Arderon (Kitton 1878), though lacking access to much of the material. Arderon published some two dozen notes in the Philosophical Transactions including several on geological subjects, but many of his observations were published by Henry Baker FRS (1698 - 1774) who with Martin Folkes (1690 - 1754), President of the Royal Society, helped and encouraged Arderon in his work. Arderon corresponded with people all over the country and a few overseas but in the main he studied geology by collecting and encouraging others to send him specimens. Unfortunately there are no specimens which can be traced back to him or his friends.

Samuel Woodward

Samuel Woodward (1790 - 1838) was a key figure in the development of geological studies in this area. He is best known for his 'Synoptical Table of British Organic Remains' (1830) and 'An Outline of the Geology of Norfolk' (1833), but a full list of his publications in a biographical paper by his grandson (H. B. Woodward 1879) shows that his interests included Archaeology and Natural History to a similar extent. Like Arderon, Samuel Woodward corresponded widely, received support from prominent men, experienced difficulties from living in the provinces; unlike Arderon an important part of his collection is still available for

study (in Norwich Castle Museum). Woodward corresponded and exchanged specimens to build up his collection, and at the same time added to the Museum collections (founded 1824) and arranged the lay-out of the geological section. His personal collection had first call on any new specimens with the Museum receiving duplicates. As a convenient means of exchange or sale he made up suites of Crag shells, mainly from Bramerton, which were well received by institutions and collectors in other parts of the country. His scientific letters from 1824 - 1838 comprise some 1500 items and give a useful picture of geological thought at the time.

A major change of direction took place in the late 18th and early 19th centuries, due largely to the practical work of William Smith (1769 - 1839) and the theoretical studies of James Hutton (1726 - 1797) synthesised by Charles Lyell (1797 -1875) in his 'Principles of Geology' (Lyell 1830 - 1833). It is interesting to speculate as to whether Woodward and his contempories were influenced by the work of these men.

In a letter to Hudson Gurney dated 17th April 1824 (Vol 1, no. 43, N.C.M.) Woodward writes: "You having mentioned Prof. Buckland in a former note induces me to solicit your obtaining his opinion as to the changes which have taken place in the outline of the German Ocean. Prof. B. is acquainted with our Norfolk coast, he has recently been down to examine its stratification in company with Mr. R. C. Taylor. Geology is a science to which I am much attached but it requires too much time for me to make any progress. I should therefore feel obliged if you could obtain a reasonable solution of the changes that I have noticed as having taken place." Gurney replied that he seldom saw Buckland and made some of his own suggestions. Taylor's publications (R. C. Taylor 1822, 1823, 1824A and B) and the presence of Buckland and others in the field led Woodward to take an

excursion from July 12 - 19, 1824, visiting Yarmouth by river from Norwich, and coastal localities from Burgh Castle to Trimingham, observing geology and collecting fossils. The impressions he gained are reflected in his theory on the history of the eastern valleys of Norfolk. Woodward was exchanging fossils freely at this time, as a note dated February 8, 1825 (Vol.1, no. 75, N.C.M.) acknowledging his fossils from the Yorkshire Philosophical Society shows, and much of the later correspondence relates to the receipt or dispatch of fossils to institutions and private collectors.

Woodward was not always successful in his approaches for information, as an extract from a letter dated June 19, 1825 (Vol. 1, no. 87, N.C.M.) from Taylor indicates: "... Without wishing to discourage you from making an interesting investigation, I must beg to decline making a transfer of data which it has cost me many years to acquire. Such a request appears both unusual and unreasonable. I have certainly accumulated many notes and illustrations of the Eastern counties, in this department, which I have been always ready, when the opportunities occurred, to communicate in the scientific publications..."

Woodward made further excursions in August 1825 and May 1826 to the north-east Norfolk coast and visited collectors, notably the Rev. James Layton of Catfield who had a series of Forest Bed fossils. Layton told him about a surgeon at Swaffham with an interest in geology, Caleb Burrell Rose (1790 - 1872). Woodward's first letter to Rose is dated May 24, 1826 (Vol. 1, no. 109, N.C.M.) and reads: "Sir, The Revd. Jas Layton of Catfield having informed me that you are about to publish a work on the Norfolk fossils, I beg to state that I have been for some time past engaged in a similar work; situated in western Norfolk you are undoubtedly fully acquainted with the fossils of that district but are you alike well informed in the fossils of eastern Norfolk? The remains of testacea & of other animals at Bramerton are exceedingly

interesting but more particularly those of the Class Mammalia (eight genera of which have recently been discovered) upon our coast. I would beg to offer my services on the work as I conceive it might render it more acceptable by embracing the fossil remains of the whole county. Dr. Yellowly was to have introduced me to your notice some time since I therefore trust that my thus addressing you will be excused & I shall be most happy in corresponding with you on so interesting a subject." There followed frequent correspondence between the two men until Woodward's death, the main subjects being fossils, the Robberds-Taylor argument and possible publications. Rose helped with Woodward's geological map in the delineation of the chalk divisions, though the map was based on that of William Smith of 1819.

Woodward and Rose took a great interest and perhaps a certain delight in the published controversy between Taylor and Robberds which involved the interpretation of beds of Crag and alluvial shells in terms of the 'deluge' (Robberds 1826, Taylor 1827A, B, Robberds 1827) and Woodward wrote to Robberds supporting the idea of a sudden deposition of shells due to the effects of the 'Noachic Deluge' (Vol 1, no. 133, N.C.M.). Robberds defended his position (Vol 1, no. 135, N.C.M.) concluding "that the earth itself, before it was inhabited by man, passed through a succession of revolutions, each occupying an almost incalculable length of ages, is indisputably proved by the clearest records of nature." Later, Woodward was himself involved in a like debate with Edward Charlesworth (1813 - 1893) who was supported by Robert Fitch (1802 - 1895), when Woodward ventured to assert that Charlesworth's Red Crag was diluvial (Charlesworth 1835A) and that the term 'Coralline Crag' was not appropriate for Ramsholt (Woodward 1835). Fitch disputed the lack of corals at Ramsholt (Fitch 1835) and Charlesworth vigorously attacked the weaknesses of Woodward's argument noting that it was

based on observations made at only one visit (Charlesworth 1835B). However Woodward attempted a short reply (Woodward 1836) and Charlesworth returned to the fray (Charlesworth 1836) citing Lyell in support; "...of late my attention has been particularly directed to those views of chronological arrangement which in so comprehensive and elaborate a manner are advocated in the 'Principles of Geology'."

Why, then, did John Gunn (1801 - 1890) style Woodward, some forty years after his death, as the 'Father of Norfolk Geology'? Perhaps he had in mind that three sons followed their father's interest in geology. B. B. Woodward FSA (1816 - 1869) studied geology in his early days, as did S. P. Woodward FGS (1821 - 1865) at Cirencester and the British Museum, and Henry Woodward FRS (1832 - 1920) at the British Museum and as editor of the Geological Magazine for many years. The grandsons interests were: B. B. Woodward FLS, FGS of the British Museum (Natural History), studied Pleistocene mollusca; B. H. Woodward, Director, Perth Museum, Western Australia; Horace B. Woodward FRS, FGS (1848 - 1914) of the Geological Survey, England and Wales; H. P. Woodward, FGS Mining Engineer; and Martin F. Woodward, malacologist and biologist at the Royal College of Sciences. It is more likely that Gunn saw the 'Geology of Norfolk' as a basis for work on the fossils of the area and the subdivision of the chalk, and I believe that this was the main impact of Sam Woodward's work. The figures of fossils from his own and other collectors' cabinets included new species, so the material is still important today. Some of the types are preserved in Norwich Museum, together with a manuscript version of the 'Geology of Norfolk' which was much larger than the final production. The main differences were in size, quarto instead of octavo, the number of plates, 24 instead of 6, the number of figures, 391 in the unfinished version, with space for many more, as against 156, and the inclusion of sections of pits. The large version was never completed though much

of the drawing work was done by 1825 and the text had been checked later by Gideon Algernon Mantell (1790 - 1852) who greatly encouraged Woodward towards publication.

Contemporaries

After Woodward's death no single collector dominated the local scene. His closest contact, C. B. Rose, began to publish results of work in West Norfolk and is well known for his papers on the brickearth of the Nar and his 'sketch of the Geology of West Norfolk,' (Rose 1835 - 1836, 1865). He followed Woodward's subdivisions of the chalk, largely disregarded and not improved upon until 1880 (Jukes-Browne 1880). Rose formed a large collection which came to the Museum after his death and contains figured material, particularly species of Inoceramus (Woods 1899 - 1913). A complete list of his papers is to be found in Horace B. Woodward's memoir of Rose (H. B. Woodward 1893) in which appears the comment: "his published papers.... remain of the highest value for reference on the districts he described."

Richard C. Taylor (1789 - 1851), one of the first to publish on Norfolk geology, moved his collection to London about 1825 and emigrated to Philadelphia in 1830 where, although he never lost contact with Norfolk, he ceased to influence geological studies in this area. His main claim to fame was an impressive, comprehensive work on the coal trade of the world (R. C. Taylor 1848).

Of the eleven collectors named in the 'Geology of Norfolk' six had substantial collections now in Norwich Museum - Anna Gurney, William Foulger, John King, G. R. Leathes, C. B. Rose and Samuel Woodward. Of the others, two from Cromer, Mr. Earl (surgeon) and Mr. Fox (lapidary), and two from west Norfolk, Edward Edwards and Henry Hoste Henley, little is known of their geological interests and their collections have apparently not survived. Anna Gurney of Northrepps Cottage formed an important early

collection of Forest Bed mammals which come directly to the Museum. Layton's collection was mainly of Forest Bed mammals; about 1828 he tried to dispose of it and subsequently left Norfolk. John King's specimens only came to the Museum in 1922, but they include valuable Norwich chalk material from localities no longer extant.

Robert Fitch (1802 - 1895), though thought of as an antiquarian because of his many publications in that field, amassed a large quantity of geological specimens which came to the Museum a year before his death. Included was a fine series of barnacles from the Norwich chalk, described by Charles Darwin as 'unrivalled' in his monograph (Darwin 1851). The lengthy correspondence from Darwin to Fitch in the period 1849-51 has formed the basis of current research (Trenn 1974).

John Gunn (1801 - 1890) formed a large collection of Forest Bed mammalia, presented to the Museum in 1868, and particularly in his middle and old age made many written contributions to local geological studies; about a hundred in all. Gunn was the most prominent local geologist for many years and the first President of the Norwich Geological Society from 1864 - 1877. His most extensive work was published posthumously, edited by H. B. Woodward in 1891.

Conclusion

It is strange that the development of a 'Deluge' theory in Britain post-dated James Hutton's condemnation of the literal interpretation of the biblical record (Boylan 1969). The English 'Scientific' diluvial hypothesis derived from the teachings of Abraham Werner (1749 - 1817) and was supported in the early 19th century by the Geological Society of London and by William Buckland (1789 - 1856) who influenced Woodward. It is against this background that the early investigations in Norfolk were carried out; the Taylor-Robberds controversy and the prevailing acceptance of the 'Deluge' by the early collectors can be understood

in this light. The 'Deluge' theory was successfully refuted and new ideas developed after 1840 when Louis Agassiz (1807 - 1873), together with Buckland and Lyell, advanced the strong case for a glacial hypothesis.

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EARTH AND LIFE SCIENCE TEACHING IN ADULT EDUCATION

R. E. RANDALL*

The sciences have been taught in Adult Education almost since further education was introduced towards the end of last century, but because many of the ideas involved are not part of everyday thought and action as in literature or history, there has always been considerable difficulty in taking the complete spectrum of the subjects to those interested to learn.

Subjects

The subjects that one can cover in earth and life science teaching in further education are legion, but the title is extremely important in connection with publicity. A poorly titled course of lectures will not attract a class of adults however interesting and informative it might be. Once a class is recruited. however, the success depends upon the method and energy of the teaching. The major factors that are noticed in successful recruitment are (i) a local element - 'The Geology of the Lake District', 'Wild Flowers of East Anglia', (ii) a personal element - 'Holiday Landscapes of Britain', 'How to Understand the Earth', 'Ecology at Work and in the Home', (iii) a modern element - 'Biosociology - a Study of Biological Sciences on Society', 'Geology Today' and (iv) a romantic element - 'Fossils', 'Britain's Best Scenery', 'Man's Place in Nature'. Courses that are merely entitled 'Geology for Beginners' or 'Ecology' rarely result in worthwhile recruitments unless the lecturer concerned is very well-known in the local area. In most cases much more thought could be given to publicity,

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both lecture title and syllabus. Where a deliberate effort has been made, larger classes result. It is almost certainly true that, when publicised in a lively and interesting manner, there are no aspects of the earth and life sciences that do not attract an adult audience.

Difficult Concepts

There is little doubt that there are difficult concepts in the sciences that add to the difficulty of teaching these subjects to adults without formal training. In geology it is undoubtedly the petrological part of the subject that suffers most severely in this respect and for that reason it is the least commonly taught. Even crystal formation though can be remarkably entertaining if the necessary supporting equipment is made use of - slides, specimens, etc. However, unless the student has a certain amount of basic knowledge in chemistry and physics there are bound to be steps which he cannot take. Therefore it seems to be inevitable that in any course of lectures which involve the use of pure science concepts, some background information must be taught as a prerequisite to the geology. The same difficulties hold true for biology where it is undoubtedly the microscopic aspects of the subject which create most learning problems. Because the chromosome and the gene are 'invisible and unreal' to the layman, he cannot appreciate their role in heredity or species development. This situation can in part be rectified by the use of 2 and 3 dimensional models, but one of the best solutions is to attempt some basic practical work as a class progresses, such as simple growth experiments which stimulate the interest and aid the digestion of the conceptual framework. It must be emphasized at this point that in virtually every adult education class, by the very nature of the participants, there is bound to be a wider range of intellect than in a comparable University or Society group, and therefore

abstract conceptual problems will be worse for some adults than others. Due allowance must be made for the fact that all learning is difficult, particularly in the evening <u>after</u> a day's work has been completed, and this will be more apparent with some students than others.

<u>Field Work</u>

Field work is an absolutely essential element of teaching in all aspects of whole organism biology, ecology and also geology. No student can have any real comprehension of the validity of propositions made and concepts discussed theoretically without testing them in the field. This is particularly true for the adult student who is only immersed in the subject for a short period each week. Without field experience he is unable to gauge the limits of reliability of the facts that are presented to him in text books and lectures, and he has no idea of the tedium and reliability (or otherwise) of data collection unless he has experienced it in a small way himself. Exactly the same argument applies to practical or instrumental work in the laboratory in biology, or the chemical and physical aspects of geology, where the adult student is inclined to accept the written statement uncritically unless he has experienced the difficulties of scientific mensuration. One of the greatest difficulties in this respect is that the majority of adult classes take place during that period of the year which is least suitable for field work. Excursions that take place in the early Autumn inevitably precede the theoretical instruction that the class will have, whereas field classes the succeeding Summer after the Easter hiatus are rarely well attended. In tutorial (3 year) classes this problem does not arise because the summers can be used, but for sessional (1 year) classes it imposes a severe restriction on what is essentially a popular aspect of scientific education. One highly successful answer to

field work difficulties is the Summer field week class.

Books

Suitable books for use in conjunction with adult education lectures were for many years difficult to obtain. However the advent of the Open University (see this Bulletin, vol. 23) has resulted in a wealth of books directed towards the adult student. American publishers, too, have produced many lavishly illustrated texts in recent years that are suitable for adult audiences, but these have the almost insuperable problem of using North American examples that are unknown or of no interest to British students. One aspect of adult teaching that seems not to be generally appreciated is the general lack of time that most class members can devote to reading around the subject. Only highly readable, informed texts of a distilled nature will be tackled in depth or at length. Therefore a great deal of care must be taken in devising the syllabus for an adult audience. This syllabus will bear little relation to the equivalent reading list for a school, or higher education class, where standard texts of the required level or journal articles can be readily included.

Meeting Places

The difficulties resulting from unsatisfactory meeting places for adult education classes are not limited to the sciences, but science teaching has the added difficulty of requiring bench space, a sink, etc. to function fully. These facilities are rarely available at a village primary school nor yet at the luxurious further education centres that fully satisfy the Arts educator. At the present time a generation of adults is reaching the classes that have been exposed to the sciences at secondary school in functional laboratories. Such students find the typical meeting place facilities

particularly unsatisfactory, as, of course, does the tutor.

Teaching Equipment

A similar problem to that of meeting places is equipment. The present-day student is no longer satisfied with the sciences being taught with chalk and voice alone, yet much of the equipment required, such as specimens, microscopes and audio-visual accessories are neither available at centres nor amenable to continued transportation. This means that many of those types of practical class that attract the adult in geology or biology can only be held in centres where the teaching equipment is available. In this respect the local education provision may often be superior to that of the peripatetic university adult educator. Nevertheless, no amount of superior equipment or lavish accommodation can determine a successful class. Virtually all adult educators in the earth and life sciences seem convinced that they can perform a successful though limited role in virtually any material circumstances so long as they can establish rapport with their class and kindle enthusiasm for their subject.

This report is the result of a questionnaire sent out to various science teachers in adult education in Britain. I would particularly like to thank the National Institute of Adult Education for supplying copies of University Adult programmes and those teachers who replied to the questionnaire.

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GEOLOGY OF THE ELY DISTRICT

(largely based on work undertaken in preparation for 'The Soils of the Ely District', 1974, Mem. Soil. Surv. Gt. Br. Sheet 173)

R. S. SEALE*

Jurassic strata

The Ampthill Clay outcrops mainly to the west of the Bedford Rivers. It could not be distinguished from the Kimmeridge Clay outcropping further east. The probable position of the boundary has been sketched in near Sutton, as it has been seen at Burystead Farm, Sutton (Forbes 1969), and in Haddenham End Field (TL 459769) (Worrsam and Taylor 1969). North of Sutton the boundary is very arbitrary, being based on topography and the boundary of acid clay. The 1" Geological Survey map, no 188, shows that the Ampthill Clay also outcrops to the south-west of Stuntney. Around Manea and between Sutton and Coveney and to the west of Grunty Fen the upper part of the Ampthill and perhaps the lower part of the Kimmeridge clays are usually acid, and give rise to the Manea soil series on the skirtland, and an acid phase of the Denchworth series. This very acid clay was not found in the soil survey of sheet 188 (Hodge and Seale 1966), or on the 2½ inch to one mile sheet TL 38 (except in one place TL 400898), either on the lower part of the Ampthill or on the Oxford clays. The pale yellow mineral jarosite, a good indicator of acid conditions, and more characteristic of the Fen Clay (see below) has been found in the solid clay, the surface of which is at about 6m (20ft) O.D. at a depth of 91-234cm in a boring at TL 47/6478, where the pH was

* Soil Survey of England and Wales, Government Buildings, Block B, Brooklands Avenue, CAMBRIDGE CB2 2DR
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about 4, and at above 18 or 15m (40 or 50ft) O.D. on possibly eroded convex sites, within the upper metre, at TL 451804 and TL 433792. The last site near Sutton is on a steep slope just below the boulder clay outcrop. There appears to be a thin band of limestone at this junction, marked by scattered rushes in the permanent grass. Water seeps out here and the clay immediately below is generally calcareous except in a few places over which this water probably does not flow. Jarosite is very common in the upper metre of the skirtland Manea series and adjoining solid clay still covered by peat, but it is rare in the clay above 3.7m (12ft) O.D. which was never covered by peat. However, it may be more common below depths of one metre on the higher ground but insufficient deep borings have been made there.

Fossils from a cleaned ditch in Grunty Fen (TL 488769) were probably within 9m (30ft) of the base of the Kimmeridge Clay (Worrsam and Taylor 1969).

Whitish tabular limestone bands often occur within the Kimmeridge Clay, e.g. in Grunty Fen (TL 553778) and on Burnt Hill (TL 4880).

Cretaceous strata

The Sandringham Sands, and perhaps the Carstone occur at Southery. Deposits of sand with ferruginous bands are far more extensive than those marked as Sandringham Sands on the old series geological maps. A boring to 275cm at Little London (TL 628948) failed to penetrate the sand. Derived phosphatised fossils probably consisting of *Trigonia* spp. and some ammonites (Forbes 1969) occur at the surface near the top of the hill (TL 626953).

The Lower Greensand was not always easy to distinguish from drift deposits. The Oakington series includes soils formed in thin drift over Greensand, as well as drift derived from Greensand. The Cottenham series, a more sandy soil, is more typical of the Greensand *in situ*.

Skertchly (1877) found a patch of Lower Greensand on the top of Thorney Hill (TL 577793), but this was not found during the soil survey, unless the patch marked as terrace drift, not verified mineralogically, (TL 579791) is in reality Lower Greensand. A small patch on Shippea Hill (TL 620840) also not verified, has been tentatively marked as Lower Greensand. It was difficult to decide in the area around Great Fen (TL 6079) whether the Greensand merges into sandy drift or not. A sample of sand collected from a ditch (TL 625871) in Burnt Fen was found to contain much decomposed glauconite and other minerals such as kyanite and staurolite, characteristic of Lower Greensand (Rastall 1913, 1919, Boswell 1916, Solomon 1932, Seale 1956). A thin layer of sandstone occurs at the bottom of this ditch. On the other hand the heavy minerals in a sand sample nearby, rather higher up the slope, where flints were more common, (TL 628872) were found to be typical of the drift deposits, there being much garnet, with relatively little kyanite and staurolite and no glauconite. The Gault is largely hidden by fen deposits. The junction with the Greensand can be seen in cleaned ditches at Castles Farm (TL 560775) (Forbes 1969). It forms a distinct ridge (TL 6487) alongside the Little Ouse River north of Shippea Hill station. Near Stuntney the Gault is about 27m (90ft) thick but it thins north-eastwards to about 20m (65ft) in Joist Fen (TL 6986) where the junction with the Chalk Marl lies about 24m (80ft) below the surface of the ground (Essex River Authority boring). The Lower Chalk forms relatively low-lying mostly rather hummocky ground, except in the north-east where it rises abruptly from the edge of the Fens in two places. Much of it consists of Chalk Marl. The Totternhoe Stone has been traced from Weston Ditch (TL 6777) to Beck Row (Jukes-Brown and Hill 1887) and is exposed in the quarry near Blackdyke Farm (TL 690886) (Peake and Hancock 1961). In Shepherds Fen (TL 6985) peat over sand, extending to depths of about 2.5 to 3.8m ($8\frac{1}{2}$ to

$12\frac{1}{2}$ft) lies over about 21m (70ft) of Chalk Marl (Essex River Authority borings).

Quaternary deposits

The Chalky Boulder Clay occurs on many of the Fen Islands and extends into the Fens beneath the peat and Fen Clay in several places in the north-east. It also occurs at a low level south-west of Stuntney (TL 5476). In Fodder Fen Common (TL 492933) the top of the boulder clay was encountered at about -3.3m (-11ft) O.D.

It is possible that Grunty Fen, which is almost completely enclosed by higher ground, originally drained eastwards into the Cam-Ouse system, and that the outlet was blocked by boulder clay. The present outlet is relatively steep-sided and cuts through the boulder clay in the north. There is a smaller enclosed fen west of Chettisham (TL 5483) with a similar steep-sided narrow outlet cutting through the boulder clay in the north, but without any other obvious pre-boulder clay outlet.

The distribution of the March Gravels shown on the map is largely based on the work of Baden Powell (1934) taking also their height above sea level into consideration. Near March they are very fossiliferous, but further south they grade into the terrace deposits and are sometimes difficult to separate from them. At Stonea the fossiliferous gravel was seen to overlie chalky boulder clay in the cutting of Harding's Drain (TL 45932). The March Gravels are now believed to date from the last or Ipswichian interglacial (Stevens 1960). Baden Powell found that they are overlain in many places by up to nearly 2m (about 6ft) of 'brickearth', which is a sandy clay, sometimes stony but never laminated.

River-terrace sands and gravels, over 3km wide, extend southwards from Stonea. They are at a lower level than the March Gravels, but merge laterally into what are probably unfossiliferous March gravels at above 3.7m (12ft) O.D. on Honey Hill (TL 435885) and Langwood Hill (TL 415850).

In the south the surface lies mainly between about 0.6 and 1.8m (2 and 6ft) O.D., but in the north the deposit is covered by peat and is mainly below sea-level. All over its outcrop there is generally an upper fine sandy loam layer, often over clay loam, passing down into calcareous coarse sandy loam and gravel which can be chalky. Together with some small isolated patches of low-lying sand and gravel south-west of Mepal this spread probably forms part of the terrace system near Earith which has been mapped as the first and second terraces of the Bedfordshire Ouse (Edmonds and Dinham 1965). A section (TL 389579) showed over 3m (10ft) of bedded chalky gravel overlain by 30-120cm (1-4ft) of brown flinty loam, which, due to extensive pitting, extended into the gravel as irregular pockets (Edmonds and Dinham 1965). Organic material in these terrace deposits near Colne, about 5km south-west of Sutton have been shown to be about 42,000 years old so proving a Weichselian age for these deposits (Bell 1970). The terraces are also related to the extensive first and second terraces near Cambridge, the upper (intermediate) terrace being of early Weichselian age (Lambert et al. 1963). The upper layer of fine sandy drift, a few inches thick, so widespread over coarse terrace deposits, and lying directly under the peat in many areas, is evidently equivalent to the 'brickearth' which Baden-Powell (1934) found above the March Gravels. This is perhaps of wind-blown origin.

In many places on the terraces (e.g. TL 4383) aerial photographs show a polygonal pattern indicating variation in plant growth, especially sugar beet, in dry summers. The polygons are often about 50-100m across, their edges evidently representing old frost cracks in predominantly loamy or sandy soil, into which fine textured material has been washed down. Crops growing directly over the old cracks are therefore less liable to suffer from drought than those between. A similar pattern has been photographed in the terrace deposits about 4km south-west

of Sutton just beyond the border of the map (West 1968). Small patches of low-lying terrace deposits occur in many places. At Shrubhill (TL 660880) they consist of coarse sub angular flinty gravel in a sandy matrix over sand (Prigg, in Whitaker et al. 1893) altogether about 3.7m (12ft) thick with the surface only 1.8m (6ft) above the level of the river (Flower 1869). Skertchly (1877) found low-lying deposits, superficially like weathered Lower Greensand, at the north-east ends of Thorney Hill and Stuntney island respectively, which he believed to be river-drift or perhaps rain-wash deposits. The Stuntney site was not identified but the Thorney Hill sand (evidently TL 577795) was investigated microscopically, and the heavy minerals were found to be typical of the drift. Heavy minerals were also investigated from other sites, several of them at higher levels (e.g. near Little Downham, TL 522843, 531840, 535838, 543838, and Burnt Fen TL 613882, 618876), which proved to be from drift and not Lower Greensand.

Much of the Chalk in the east and south-east is covered by coarse sandy drift, sometimes gravelly, which extends into the Fens. This drift is similar to, and continuous with that in the Brecklands. A characteristic feature of this area is the 'hills and holes' micro-relief. This is especially well developed on the sandy drift of Mildenhall and Hockwold Fens, and is also characteristic of the low-lying chalk regions. It has been described in general by Sparks et al. (1972), to the south of the mapped area by Hodge and Seale (1966) and Worrsam and Taylor (1969), near Eriswell (TL 7179) by Perrin (1966) and in parts of the Brecklands by Corbett (1973). On the low chalk mound at Kennyhill (TL 6780) the hummocks are undulating, often discontinuous, chalky ridges up to 1 metre high, which contrast with the deeper rather darker soil between when the land is ploughed. Towards the north-east (TL 6981), where the ground, ranging between 1.5 and 4.8m (5 and 16ft)

O.D., is rather higher, the oval or circular hollows range from about 50-200m across, with a maximum vertical dimension of about 2.75m but they are less distinct higher up. On the sandy drift the hollows are filled with peat, peaty loam, shell marl, or sand, or mixtures of these. The surface of the hollows is often 2m below the tops of the ridges and the peat infilling can extend down a further 2m or more. The hollows are often about 50m across. Many are smaller, though occasionally they are up to 500m long and 150m wide. Sometimes they are completely obliterated by blown sand. In Hockwold Fens especially, only the tops of the sandy ridges may appear above the level of the peat fen, while in parts of Feltwell Fens the presence of hummocky ground may only be detected by differences in the depth of the peat. In one place (TL 6890), although the surface is level, the peat over Chalk Marl ranges in depth from about 0.6 to nearly 2m over short distances.

High level sands and gravels of uncertain age occur on the summits of several of the Fen islands. Near Sutton (TL 450795) the deposits may be of glacial origin. Other deposits, possibly representing high terraces, occur on sloping ground (TL 440785, 443765, 446817). In two places close to the main river banks the possible terrace deposits have not been checked by boring (TL 580840 and 577863), although the surface appeared sandy and rather gravelly.

The main rivers probably flowed in almost constant courses from the retreat of the ice until historical times. The final channels before diversion are now represented by old ways, roddons or old runs (Fowler 1932, 1933, 1934A and B).

Detailed sections of the lateral relationship between the main river channels and the 'backwater' area have been made near Ugg Mere between Huntingdon and Peterborough (Godwin and Clifford 1939), at Shippea Hill (Clark 1933, Godwin and Clifford 1939) and Old Decoy Farm (Jennings 1950), the latter data concerning the Little Ouse being

supplemented by Soil Survey work. Sections of the Little Ouse roddon, about a mile apart, which show a complicated history of erosion and deposition, were investigated at Plantation Farm, Shippea Hill (TL 644848) and Old Decoy Farm (TL 658853). The immediate post-glacial channel of the river was about 1.5 to 3.4m below the general level of the fen floor. It was bounded by sand banks about 180 to 300m apart and rising 1 to 3m above the fen floor. These sand banks were occupied by man in Mesolithic, Neolithic and Bronze age times (Clarke 1933, Clark _et al_. 1935, Godwin and Clifford 1939 and Godwin 1960). The sand stands up above the peat in several places (TL 627847, 613843, 636854, 639848, 659856, etc.). The other main rivers flowed in comparable deep channels. One, along the old course of the Cambridgeshire Ouse, was proved at Prick-willow railway bridge, and (on Sheet 188) at Dimmock's Cote road bridge, where firm foundations on the Kimmeridge Clay floor were not found till depths of about 10m (42 and 40ft respectively) had been reached, whereas nearby the clay is usually not more than 3.7m (12ft) down (Fowler 1934 A and B).

Peat assigned to pollen zone IV (Godwin 1940) was formed in the deep river channels before about 7500 BC (Godwin 1960), but it does not appear to have spread over the greater part of the fen basin much before 3000 BC (Willis 1961), though Godwin and Clifford found peat dating before 5000 BC at Queen's Ground, Methwold Fens. The peat is thickest in Joist Fen (TL 6986) and Isleham Fen (TL 626765) in the ancient channels of the Little Ouse and Lark respectively. Thick peat also occurs north-east of Sam's Cut Drain in Methwold Fens and in parts of Feltwell Fens, east of Cross Bank, where the land has only recently been adequately drained. Moderately thick peat also occurs north-west of Ely in Padnal Fen, between Ely and Stuntney in Middle Fen, in parts of Mildenhall Fen, in North Fen, in the Bedford washes and in a few small places west of the Bedford Rivers.

The Lower Peat lies beneath the Fen Clay on the mineral floor of the Fen. Beyond the limits of the Fen Clay it passes imperceptibly into the Upper Peat and its upper limit cannot be distinguished in the field. In the central regions few borings penetrated the Lower Peat, and it appeared from this limited evidence that the Lower Peat is seldom much more than a metre thick in the Cambridgeshire Ouse Basin, thinning out to 0.1m in places, even in the central regions (e.g. TL 557934). It is up to 1.5 metres thick in the basin of the West Water in the south-west and to the south of March. Further west, between Benwick Mere and Warboys, Hunts, this thickness appears to be maintained in this basin over wider areas, even near the southern boundary of the Fen Clay. Apart from some Boulder Clay in the north-west, Jurassic and Gault clays, generally with a thin(?) sandy covering, appear to underlie the Lower Peat over the deeper parts of the Fen Basin around Ely.

The Fen Clay marine transgression began about 3000 BC in the north and was apparently at its maximum at about 2,250 BC when it extended as far as Wood Fen north of Ely. Willis (1961) states that this phase ended here at about 2,200 BC and was completed in the north at about 2,000 BC. He suggests that at any particular place 300 or 400 years of Lower Peat formation preceded the clay deposition. The peat covering the Fen Clay has now largely disappeared revealing the network of roddons over it. The majority appear to be contemporaneous with, and their deposits merge into, the Fen Clay. The roddons form a dichotomous network similar to the creek pattern found in present day salt-marshes, and it seems probable that the Fen Clay was formed in this manner. The deposit is unconsolidated, and wedge shaped in vertical section, being thickest in the north and thinning out towards its edges in the south. Sometimes there are interdigitated layers of peat within the Fen Clay near its margins, but often the edge is more abrupt. South of Butcher's Hill (TL 5390), Fen Clay 2.6m thick was found within 100m of its margin. In places, instead of thinning,

the clay may gradually become more organic with increasing reed-remains towards its edge. It extends for some distance up the main river channels. Few borings penetrated the Fen Clay in its central regions. In Cranmoor Lots (TL 491933) it is about 2.4m (94in) thick on about 0.15m (6in) of Lower Peat over Boulder Clay. In Burnt Fen (TL 592875) 3.6m of Fen Clay lies on 1.5m of Lower Peat on a sandy substratum.

The roddons, with their calcareous silty deposits largely thin out towards the boundaries of the Fen Clay, and where the top of the Lower Peat is above the water-table and the Fen Clay is thin, it is generally very acid and contains jarosite or natrojarosite ($KFe_3(SO_4)_2(OH)_6$ and $NaFe_3(SO_4)_2(OH)_6$) (Brown 1960, Soil Survey Staff 1960). These minerals also occur in those parts of the substratum above the water-table. Jarosite is present in thicker Fen Clay, though much less commonly. In the Fens it appears to have formed since drainage.

The Upper Peat was formed over the Fen Clay but much of it has wasted away. It is still 2m or more thick north-east of Southery and within the Bedford wash, where it is preserved by a covering of alluvium. It exists beneath the Romano-British silty alluvium north-west of Welney where it is generally about 75cm thick, though ranging between about 40 and 140cm thick.

The Old Fen Meres were shallow lakes in the marshes, usually no more than 60-90cm (2 or 3ft) deep, in which shell (or *Chara*) marl was deposited. Redmere was the largest of these lakes, with shell marl about 1 metre thick over most of its area. Another lake 'Lesser Redmere' (TL 635875) appears to have been ponded against the present banks of the Little Ouse. Here the marl varies from about 20-60cm thick, over 15-90cm of Upper Peat, 15-70cm of Fen Clay and about 15-30cm of Lower Peat, over the sand or sandy clay loam of the fen floor at a total depth of about 2.1 to 2.4m. A distinct channel therefore cuts through the

ridge on the south-west side of the Little Ouse. In Feltwell Fens a considerable area of shell marl, 25cm to over 1m thick, still has a covering of peat. Smaller shell marl patches under a layer of peat occur in Mildenhall Fen. Redmere itself is mostly beyond the limit of the Fen Clay. Here shell marl lies over about 2-2.35m of peat in the north, thinning to 60 or occasionally as little as 25cm in the south. Patches of shell marl are common to the east of the old Cambridgeshire Ouse and between the old river and the high ground of Ely and Littleport and to the north of Littleport, but very rare to the west. Thin shell marl does occur associated with the West Water, the course of the old Huntingdonshire Ouse in the south-west, but these deposits are mostly covered by about 30cm or so of humose alluvial clay believed to date from 180 AD (Coles and Liversidge 1965, Worrsam and Taylor 1969 and Salway et al. 1970). One minute isolated patch of shell marl occurs near March (TL 436945).

Apart from Harrimere (TL 536766) none of the meres appear on any of the maps, unlike those further south and west, and no records exist about them. On a hillside south of Ely (TL 535792 and 540796) there are two small deposits of silty clay loam with freshwater shells which fan out onto the flatter ground below. These probably mark the site of springs. Arather similar deposit occurs on flatter ground on the river terrace (TL 417849) where there was evidently a pond.

Some watercourses, beyond tidal influence, are now marked by a shell marl called old slades (Fowler 1934A), there are a few of these associated with the River Lark and its diversions and one north of Shippea Hill.

River Clay occurs in the south-west associated with the West Water. It is generally between about 30 and 50cm thick and lies over about 60-90cm of Upper Peat. It is a very fine deposit, sometimes with over 90 per cent

clay (<2μ e.s.d.) and it extends to the south where it is often thicker (Edmonds and Dinham 1965, Worrsam and Taylor 1969). Clay or silty clay has also been deposited by floodwater near Ely (TL 5781), between the embankments of the modern rivers and in parts of the wash between the Bedford Rivers. This wash was formed in 1650 when the New Bedford River was constructed. The maximum depth of the clay is now 60cm near the south-western end, but 20-30cm is a more general thickness. The clay thins across the wash towards the Old Bedford River.

The estuarine silts of the Romano-British marine transgression occur at Welney, and extend up the old courses of the Cambridgeshire Ouse and Little Ouse and up Darcy Lode in the north-west. A study of the foraminifera in the silt proves their marine or estuarine origin (Macfadyen, in Godwin 1938). Apparently, in contrast to the rather lobate form of the earlier Fen Clay transgression, the deposits in the tidal creeks extended beyond the main deposition areas, with peat formation between the levees of the larger watercourses, which must have stood out above the general level of the marshland as in the present day north-west German marshes, where the raised silt land is called 'Hochland' and the intervening peat land 'Sietland' (Godwin 1938). The calcareous silt, which stands up to 3m (10ft) O.D., changes laterally into the adjoining peatland through a fringing zone, sometimes up to 500m wide, of humose non-calcareous clay, sometimes containing jarosite, perhaps representing an area where a very slow tidal flood, carrying suspended clay, percolated into a peat-forming vegetation. This fringing zone, becoming narrower upstream, borders the old courses of the Cambridgeshire Ouse and Little Ouse, its acidity contrasting strongly with the calcareous silts of the roddon ridges. North-west of Welney and in Upwell Fens the ground surface is very uneven. The Old Croft River on the

county boundary follows along the course of the old river with high silt banks on either side. Beyond these banks there are irregular or rounded depressions often 2 or 3m deep, of all sizes ranging up to 200m or more across. The soil in these hollows is almost invariably of finer texture than that higher up. It seems probable that the fringing clay deposit described above extends beneath much of the estuarine silt and is exposed in the deeper hollows. This layer, separating the silts from the Upper Peat beneath, is generally about 20-60cm thick. It does not extend under Darcy Lode or the main river channels, where the silt deposits cut into both Upper Peat and Fen Clay. On the other hand the clay may represent a period of freshwater flooding contemporaneous with that associated with the West Water in the south-west. A study of the foraminifera would probably throw light on this problem.

The River Lark was evidently diverted in Roman times (Fowler 1934A), before the extensive silting-up of the canals which branched off the old Cambridgeshire Ouse and now stand up as distinctive roddons. One of these canals joined the Ouse a short way above the Old Lark and its roddon is much higher and more distinctive than that of the Lark. West of Chatteris the estuarine silts did not penetrate nearly as far up the West Water.

Groups of short parallel roddons occur in the north, standing up to 2m or so above the surroundings (TL 4795, 4895, 5194 and 5394). They are probably silted-up Roman drainage ditches; the least disturbed group (TL 5394) is within the Bedford wash (Astbury 1957, Salway _et al_. 1970).

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MAP OF THE GEOLOGY OF THE ELY DISTRICT

(largely based on work undertaken in preparation for 'The Soils of the Ely District', 1974, Mem. Soil. Surv. Gt. Br. Sheet 173)

R. S. SEALE*

This map is issued with Bulletin No. 25 of the Geological Society of Norfolk on a separate A3 sheet at a scale of very approximately 1:75,000.

A master dyeline copy of the draft map on a scale of 1:63360 (1" to the mile) is held by the Cartographer, School of Environmental Sciences, University of East Anglia, Norwich NOR 88C. Dyeline copies of this draft master, at that scale, can be supplied by him if required at a charge of 60p including postage and packing.

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Quaternary	Flandrian		River Clay	
			Shell Marl	
			Peat	
		ez	Estuarine Silt (Romano-British)	
		ec	Estuarine Clay (Romano-British)	
			River Deposits (Bronze age to early Romano-British)	
		fc	Fen Clay	
	Devensian	0	Low-lying Sands (Coversand?)	
		1	First Terrace ?	River Gravels
		2	Second Terrace ?	
	Ipswichian		March Gravels (Marine)	
	Wolstonian ?		High-level Gravels	
	Anglian		Chalky Boulder Clay	
		Unconformity		
Upper Cretaceous	Cenomanian	h 5a2	Upper Beds	Lower Chalk
			Totternhoe Stone	
		h 5a1	Chalk Marl	
Lower Cretaceous	Albian	h 3-4	Gault Clay	
	Lower Albian & Aptian	h 2	Lower Greensand	
		h 2c	Carstone	
Lower Cretaceous/Upper Jurassic ?		h 2s	Sandringham Sands	
		Unconformity		
Upper Jurassic	Kimmeridgian	g 12	Kimmeridge Clay	
	Corallian	g 11e	Ampthill Clay	

Built up areas, quarries, airfields & other disturbed ground

Geological boundaries

Geological boundaries beneath one superficial layer

Geological boundaries beneath two or more superficial layers

Peat boundaries

Key to Map of the Geology of the Ely District

SECRETARY'S REPORT FOR 1973

There were seven lecture and demonstration meetings in 1973. January 'Demonstration of techniques', at the School of Environmental Sciences; February, Mr. I. Richardson, 'The Hydrogeology of Norfolk'; March, Mr. J. Goff, 'On some aspects of the Catton Sponge beds'; April, 'Members' specimens'; October, Mr. B. McWilliams, Presidential Address 'The Place of Early Collectors in the development of Geological Studies in Norfolk'; November, Mr. P. Cambridge, Professor B. M. Funnell and Mr. N. Peake, 'The Geology of the Norwich Area - A Review'; December, The Annual General Meeting, followed by a showing of the film 'When Polar Bears Swam in the Thames'.

There were three Committee Meetings during the year.

1973 was my first year as Secretary following the retirment of Mr. B. McWilliams. This report therefore gives me the opportunity to express, on behalf of the Society, our thanks for all that Brian McWilliams has done for the Geological Society of Norfolk during his tenure of office, an important period in the Society's history. On a more personal level I should also like to thank him and the rest of the Committee for the help given to me in the somewhat daunting task of following in his footsteps.

A new Secretary taking over at the beginning of the year has the advantage of a Winter Programme already prepared. However, the new year was marked by a change in venue in that lecture meetings moved to the University. This has the disadvantage of relative geographical remoteness in that it is on the outskirts of the city and not, like the Museum, centrally placed. However, it is heartening to see that members have not found this too much of a barrier and attendances at meetings have remained at an encouraging level.

Following circulars to members to solicit opinion it was decided to transfer meetings from Thursdays to Mondays. This was first carried out in November.

Membership has continued to grow steadily and in general the GSN is in a healthy state. That it should continue to be so depends largely on the Committee being able to provide a stimulating programme of lectures, field meetings and publications. I should be grateful, therefore, if members would always feel free to contact me either at meetings or in writing if they have any suggestions on any aspect of Society business.

January 1974 Christopher J. Aslin

Key to Map of the Geology of the Ely District

Quaternary	Flandrian		River Clay	
			Shell Marl	
			Peat	
		ez	Estuarine Silt (Romano-British)	
		ec	Estuarine Clay (Romano-British)	
			River Deposits (Bronze age to early Romano-British)	
		fc	Fen Clay	
	Devensian	0	Low-lying Sands (Coversand?)	
		1	First Terrace ?	River Gravels
		2	Second Terrace ?	River Gravels
	Ipswichian		March Gravels (Marine)	
	Wolstonian ?		High-level Gravels	
	Anglian		Chalky Boulder Clay	
			Unconformity	
Upper Cretaceous	Cenomanian	h 5a2	Upper Beds	Lower Chalk
			Totternhoe Stone	Lower Chalk
		h 5a1	Chalk Marl	Lower Chalk
Lower Cretaceous	Albian	h 3-4	Gault Clay	
	Lower Albian & Aptian	h 2	Lower Greensand	
		h 2c	Carstone	
Lower Cretaceous/Upper Jurassic ?		h 2s	Sandringham Sands	
			Unconformity	
Upper Jurassic	Kimmeridgian	g 12	Kimmeridge Clay	
	Corallian	g 11e	Ampthill Clay	

Built up areas, quarries, airfields & other disturbed ground

Geological boundaries

Geological boundaries beneath one superficial layer

Geological boundaries beneath two or more superficial layers

Peat boundaries

ELY
g11e
fc
ez
ec
1-2
g12
g11-12
h2
0
1
2
0
1

3 4 5 6 7 8 kilometres

2 3 4 5 miles

Issued with:
Bull. geol. Soc. Norfolk, 25, 37 - 38 (June 1974)

MAP OF THE GEOLOGY OF THE ELY DISTRICT

(largely based on work undertaken in preparation for 'The Soils of the Ely District', 1974, Mem. Soil. Surv. Gt. Br. Sheet 173)

R. S. SEALE*

> This map is issued with Bulletin No. 25 of the Geological Society of Norfolk on a separate A3 sheet at a scale of very approximately 1:75,000.

A master dyeline copy of the draft map on a scale of 1:63360 (1" to the mile) is held by the Cartographer, School of Environmental Sciences, University of East Anglia, Norwich NOR 88C. Dyeline copies of this draft master, at that scale, can be supplied by him if required at a charge of 60p including postage and packing.

Reference

Seale, R. S. 1974 Geology of the Ely District. Bull. Geol. Soc. Norfolk, 25, 21 - 36.

* Soil Survey of England and Wales, Government Buildings, Block B, Brooklands Avenue, CAMBRIDGE CB2 2DR
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CONTENTS Page

The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

Visitors are welcome to attend the meetings and may apply for election to the Society. For further details write to the Secretary: Dr. C. J. Aslin, The University Library, University of East Anglia, NORWICH NOR 88C.

Copies of this Bulletin may be obtained, 60p (post free), from the Secretary at the address given above; it is issued free to members.

Also available, at 75p (post free), is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.

BULLETIN OF THE GEOLOGICAL SOCIETY OF NORFOLK

No. 26

CONTENTS INCLUDE:

The nature and assessment of Fieldwork in geology

Hunstanton fossils

FIELDWORK ASSESSMENT SPECIAL ISSUE

BULLETIN of the GEOLOGICAL SOCIETY OF NORFOLK
No. 26 September 1974
Editor: R. S. Joby,
116 Gowing Road, NORWICH NOR 40M

EDITORIAL

This edition is largely devoted to a seminal article on the nature and assessment of fieldwork in geology by David Thompson of the Department of Education at Keele University. Mr. Thompson holds the first appointment at an English university in geological education, and is therefore well equipped for this task. It is hoped that this article will be widely read, and I will gladly consider any comments or rejoinders from readers.

The growing importance of geology as a school subject has been seen in previous articles in this series, and I think that Mr. Thompson makes a good case for the key importance of fieldwork within syllabus study. His article should certainly be given to head teachers who have doubts about allowing time and funds for its pursuit.

There is only a little room left for our other item, a note from Hamon Le Strange, well known for his collecting in the Hunstanton district and his generous help in hiring an excavator for fieldwork on Hunstanton beach. More of his material can be included at a later date.

Bulletin No. 27 will be issued in April 1975. Contributions should be sent to me as soon as possible and no later than December 31, 1974.

Will contributors please note that manuscripts are acceptable in legible handwriting, although typewritten copy is preferred. In either case it would be a great help if details of capitalisation, underlining, punctuation, etc., in the headings and references (particularly) could conform strictly to those used in the Bulletin. Otherwise publication may be delayed.

Illustrations intended for reproduction without redrawing should be executed in thin, dense, black ink line.

Thick lines, close stipple, or patches of black are not acceptable, as these tend to spread in the printing process employed. Original illustrations should, before reproduction, fit into an area of 225 mm by 175 mm; full use should be made of the second (horizontal) dimension, which corresponds to the width of print on the page, but the first (vertical) dimension is an upper limit only. All measurements in metric units, please.

R.S.J.

Bull. geol. Soc. Norfolk, 26, 3 - 46 (September 1974)

THE NATURE AND ASSESSMENT OF FIELDWORK IN GEOLOGY

D. B. Thompson*

1. Introduction

In conversation, teachers of geology at all levels (CSE, O, A and university) indicate that they regard the doing of fieldwork to be the basis of the study of the subject. Hence even at school, teachers are keen to take their students into the field despite the difficulties of finance, distance to outcrops, loss of holiday time, disruption of the school programme, the risk of incurring the odium of colleagues (some of whom regard all trips outside school as 'play'), and the need to enlist the services of another member of staff. Are they right in wanting to do fieldwork?

Often it is apparent in conversation that school teachers, even some university teachers, are not clear about what they should do, or why they should do what they do, in the field (see for example University of London geology conference, 1973). This may be because some school teachers have little geological background and no training in teaching science. Often schoolteachers with geographical training may, or may not, wonder how geological fieldwork should differ from geographical. What should be the nature and purpose of geological fieldwork at CSE, O and A level?

A great number, however, who know their minds, are keen to have fieldwork assessed because they say it is so important (e.g. in an 'A' level survey: Thompson, 1969). In that study some teachers wished to have a considerable percentage of marks set aside for the assessment of field-

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work, but they were unclear as to how the assessment procedure should be devised. Should the fieldwork be treated as a piece of project work as in many CSE subjects and university mapping theses? In any case by what criteria should it be assessed?

By far the greatest amount of fieldwork is carried out during university courses. Does their procedure commend itself to schools? Surprisingly few manuals exist which discuss or detail the skills concerned in fieldwork at this level and most of these are rather dated and mostly concerned with field mapping (Geikie 1900, Grenville-Cole 1903, Willis 1923, Greenly and Williams 1930, Lahee 1961, Kottlowski 1965, Harpum 1973). Himus and Sweeting (1951) is the only work which could be said to be suited to school use. Most university training is accomplished by group, or rarely personal tuition, often by personal example, followed by practice on relatively uncharted ground at distant places, often abroad. Traditions vary enormously. In most cases at university level the teaching of fieldwork skills is not assessed directly except by marking a mapping thesis. It is interesting in this context that in the last few years Oxford University have had one finals paper taken in a hitherto unvisited quarry wherein students can be observed and assessed in all that they do, by both internal and external examiners. Their mapping thesis is treated as a separate exercise. None of these procedures could be easily translated in their entirety to the school situation.

2. Should fieldwork be undertaken?

Considering how little fieldwork is emphasised in official syllabuses (see Tables 1, 2, 3) the literature on the virtues of geological fieldwork in education is surprisingly strong. Quotations will suffice to give an indication of the high position in which fieldwork has been regarded:

British Association for Advancement of Science (1937, p.283) "Geology taught without proper regard to the phenomena which the pupil can observe and study for himself must become dull and unreal."

J. Platt (1946, p.20) "Any attempt to neglect the practical and out-door aspects and to teach the subject in any other way will be doomed to failure ... Moreover, it will follow that his scholars, being likewise obliged to depend upon the observations of others, will soon become quite content to do so, and thus the teaching will fail in its object to train the powers of observation, the whole value of its training in scientific method will be lost and the chief objects of its inclusion in the curriculum will be frustrated."

(p.18) "The subject supplies ample scope for true scientific training, training in observation, in the investigation of observed facts, in the testing and applying of inferences, and in their interpretation and classification."

V. Wilson (1947, p.4) "Secondly, I cannot plead too strongly that any programme of instruction in geology in schools must at all times stress the pupil's experience in both the subject matter and method of science. Early every-day experiences if not rationalised into knowledge soon become evanescent as the child grows older. His restless observation should be encouraged and made as accurate and complete as possible, and only when his acquaintance with geological phenomena is becoming tolerably exhaustive should he be introduced to the new sources of information which our textbooks supply. In teaching geology we must not put theories, definitions, rules and principles first, but disclose them as they come in the order of nature through the study of examples."

J. Greensmith (1958, p.107: re Secondary Modern Schools) "Whenever possible, the pupils should be allowed to construct their own clinometer from a protractor and in provided notebooks encouraged to accurately record pertinent information. Moreover, the drawing of simple sketches showing the main geological features exposed at various localities should be attempted. An estimate of the thickness of beds exposed is usually possible and, if conditions are favourable, the more able can accurately measure bed thickness by tape or rule, or by using simple trigonometrical methods. Finally, the idea can be put forward that junctions between beds (or groups of beds) can be reasonably accurately followed by the use of exposures, topography and soils. With the teacher's assistance it may then be possible for the pupils to plot more obvious junctions in the local rocks on to the Ordnance Survey map, thus building up a local geological

map. Naturally this process will, and indeed should, take time and may prove impractical for many reasons."

(1965, p. 482: re C.S.E.) "The basis of the syllabus, and its attendant examination, is as far as possible the immediate school area. The pupils should be encouraged to inspect the local rocks and scenery as much as possible despite timetable disorganisation."

George _et al_. (1967, p.65: re Secondary Modern schools) "... geology only comes to life when the pupil himself becomes a geologist ... Geology then is an intrinsic part of field study and the end of the teaching exercise is to give the pupil some understanding of the geological processes and products he himself has seen. Excursions, therefore, should form an accepted, central part of the teaching of geology, and should indeed be the peg upon which geology hangs. ... insufficient concern with processes may result in the pupil's failing to understand the significance of the products as he sees them in the actual rocks and in the specimens he collects in his own neighbourhood."

Bradshaw _et al_. (1970, p.77: re O level) "Geology should therefore provide the student with training and experience in observation, measurement and interpretation; ... The emphasis placed on a scientific approach to geology is important. ... Field-work is the only way in which the full evidence available can be appreciated, and should form an important component of the course."

Bassett's address (1971), much quoted elsewhere in this article, clearly supports the case that fieldwork should be given greater prominence. Perhaps the literature has been overlooked. Perhaps the teachers have not had access to it, or if they had, they may not have drawn the attention of the Boards to the recommendations. Perhaps the Boards did not listen or did not have antennae to receive the comments available. The possibilities are endless and speculative, but herewith is a verbatim quote from a report which dealt with A level and was based upon replies from nearly 20% of the membership of the Association of Teachers of Geology. This may dispel some speculations.

Thompson (1969, p.9 - 10: re A level) "_Fieldwork_ . The time given to fieldwork at A level was as follows (in days):

YEAR	MEAN	MAX	MIN
1	5.93	20	0
2	5.36	15	0
3	6.70	11	0

General comments. One Cambridge member said that fieldwork was not really required, another that boys were not available at weekends and classes could not be disturbed during the week. London and J.M.B. members thought fieldwork was inadequately examined and that examinations could be passed without real fieldwork. Guidance was needed by some on the type of fieldwork to be done. Others thought it wrong that London teachers should grade the fieldwork of their own pupils: they wanted an examiner to mark it. One thought it should be an option. One Northern member requested an oral examination, another a compulsory question. One Oxford school reported that only solving of simple maps was required and suggested that more questions should require field knowledge.

Mapping and detailed measurement. Several London members encouraged their pupils to make geological maps and measure sections, sometimes the latter as an alternative to the former. Many J.M.B. schools did such work. One member asked that simple mapping be included in the syllabus, since students enjoyed the freedom and responsibility of the exercise. Another suggested that it was appropriate only for the 3rd year sixth since it took so much time. One Oxford and Cambridge school mapped and measured: another did not. Welshmen noted that nothing was specified in the syllabus, that work varied with the enthusiasm of candidates, that more could be done. One said that the measuring habit was essential.

Cook's Tour geology. Most agreed that some of this work was useful early in the course in order to increase awareness and regional experience. It was said, in moderation, to be an excellent method of teaching (L). Other members disapproved heartily (C, N), but noted that this kind of work adequately covered examination needs and was therefore the only type done. In Wales this work, coupled with sample study and sketch maps of photographs, appeared to be the main experience sought."

At the end of the report (p.11) some recommendations were made by teachers. They asked that:

"(e) A means be devised of examining fieldwork (L, N). The type of fieldwork required should be stated clearly in the syllabus.

(s) Field techniques be emphasised."

[C = Cambridge Local Board L = London Board N = Joint Matriculation Board]

A damper is provided by Paling (1969, p.5):

"Unfortunately the idea has grown up amongst some teachers that the only geology worth doing is that which is carried out in the field. Nothing can be imagined more likely to antagonise the average headmaster. From his standpoint, subjects suitable for the curriculum must fit into thirty-five or seventy minute periods in the classroom; regular afternoons off for "frolics in the country" are unthinkable. It is certainly true that pupils should visit quarries and other places where rocks can be examined in situ and specimens collected. Such excursions, however, can be arranged at the end of term or other convenient times. Some interested pupils are prepared to carry out fieldwork in their own time and seem able to persuade parents to provide transport. In any case it would be a very restrictive course which dealt only with local geology."

Despite the last comment, there is every reason to treat fieldwork as the one aspect of geology that is most basic and hence to have pupils do it whatever the odds.

3. Fieldwork in present school syllabuses

(i) Introduction

A review of the demands made by syllabuses and the guidance given by CSE and GCE boards reveals that much is unclear and unspecified. Except in odd cases teachers do not have much clue as to what is 'officially' expected. The wording of passages which refer to fieldwork is often strong only in the sense that it indicates an obligation or near obligation to do some. The passage is often framed in a manner which suggests that it can be used as a stick with which to beat an uncomprehending headmaster or LEA when funds are needed to support fieldwork. But what kind of fieldwork? It is assessed? If so, by what criteria?

(ii) Present arrangements

The following tables (Tables 1, 2, 3) give an indication of the arrangements. Only the Associated Examining Board and the Welsh Joint Education Committee

put fieldwork at the beginning of the syllabus and treat it as a priority. Others mention it and tuck it away, often in the middle or at the end of the syllabus, in as few words as possible.

(iii) Criteria upon which fieldwork is really assessed

Since in so many cases criteria for assessment are either unstated or inadequately described, the author has attempted to piece together from unofficial sources (i.e. teachers of CSE, O level, A level and retired examiners) what criteria <u>are</u> used. These sources indicate that the following evidence is looked for:

1. Real experience in the field as opposed to faked experience (i.e. classroom dictation, textbook diagrams): a commonsense measure of "Has proper geological work been done?"

2. The work being written-up in the field as opposed to being written-up in the classroom.

3. The content being geological as opposed to geographical.

4. The degree of fullness and completion of the work.

5. The variety of geological experience.

6. The variety of localities visited in a local area. Some emphasise that a small area should be worked on foot rather than scattered localities worked by coach.

7. The variety of rocks studied, i.e. igneous, sedimentary, metamorphic; mineralised and fossiliferous.

8. A variety of rocks of different ages.

9. The quality of expression in the field report.

10. Neatness.

11. The presence of many diagrams of seeming accuracy and quality.

12. The individuality and originality of writing-up.

TABLE 1 FIELDWORK REQUIREMENTS:

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
AEB 1973	not stated	Notes. A pamphlet on fieldwork is produced but unfortunately a copy has not yet come to hand *	Making field sketches *
Cambridge Local 1974	10 minimum	The study of a district and the maps of the District. Practical work to illustrate theoretical topics. Reference to structure and relief, the position of springs, the geological distribution of soils, economic products of economic importance	a. Personal observation b. The examination of rocks, minerals and fossils in the field.
JMB 1974	not stated	Any area. Experience in the field. To study the distribution of rock types, fossils, sedimentary and tectonic structures, geomorphic phenomena	Personal observation Experience in the field

AEB = Associated Examining Board

JMB = Joint Matriculation Board

* But see addendum re booklet "Suggestions on the organisation of fieldwork"

ADVANCED LEVEL OF GENERAL CERTIFICATE OF EDUCATION			
Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
Practical note-books to be submitted: to include original field notebook	Teacher to certify authenticity of the work	None stated	10% for all practical books
Not stated but possibly in answers to theory questions	Not stated but possibly through questions in theory paper which are not compulsory	Not stated	None to a little. Depends on choice of questions
a. By original field note-book (not fair copies), b. By illust-ration of answers in theory paper	a. Inspection of field-notebook b. By questions in theory paper.	Not stated	None, but may be used to upgrade borderline candidates or gain odd marks in theory paper

TABLE 1 continued overleaf

TABLE 1 continued

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
London 1973 and draft of new syllabus	10 minimum	An area of the school's choice	a. To undergo adequate instruction b. To become familiar with the geology of a selected area c. Noting personal observations d. To make personal measurements e. to make personal sketches or photographs and annotate them.
Oxford Local 1975	not stated	Unspecified	Ability to keep a record of fieldwork
Oxford and Cambridge 1974	not stated	Study of a district	a. Field observation b. Deductions from observation
WJEC 1974	not stated	Study of a small area by the candidate in isolation or by the class as a group.	a. Experience of study in the field b. Displaying specimens c. Writing a field report

WJEC = Welsh Joint Education Committee

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
Original field notebooks brought to practical	External marking of field note-books	Criteria used by examiners but cannot be divulged	?
By reference in theory papers where relevant	Via answers in theory papers	Not stated	Odd marks may be gained in theory papers
By reference in theory papers	Via answers in theory papers. Question on field work in theory paper but not compulsory	Not stated	None to a little. Depends on choice of questions
a. Display of specimens b. Field reports of individual or group work	Assessment an integral part of the examination	Not stated	?

TABLE 2 FIELDWORK REQUIREMENTS:

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
Cambridge Local 1974	Not stated	School area or another selected area. Reference to local geological maps. Collection of specimens.	a. Examination of rock exposures b. Observation of agents of erosion and deposition. c. Simple field-sketching.
AEB 1974	3 half or 3 full days	Any area. Stress to be placed on application of geology to every-day life. *See addendum re booklet "Suggestions on the Organisation of Field Work" (O level and A level) 1974.	Adequate field training a. Note-taking b. Field-sketching * See addendum re booklet.
JMB 1973	Not stated	Study of geological phenomena and structures.	None stated
London 1975	3 half or 3 full days	Not stated	Not stated
Oxford Local 1975	Not stated	a. Any area. b. Collection of rocks, minerals, fossils c. Reference to geological maps	a. Observation and recording of processes of erosion and deposition. b. Observation and recording of relationship between geology and scenery. c. Simple field-sketching. d. Recording textures and structures of rocks.

AEB = Associated Examining Board
JMB = Joint Matriculation Board

ORDINARY LEVEL OF GENERAL CERTIFICATE OF EDUCATION			
Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
None	Via questions on the theory papers	Not stated	Small variable % via answers in theory papers
Practical books to be handed in with lab work and fieldwork (original field notebook)	a. Teacher certification of authenticity. b. Not stated	Not stated	10% for practical books
In answers in the theory papers	Via questions on the theory paper	Not stated	Small variable % via answers in theory papers.
Field notebooks sent to the university	Unspecified in syllabus. "Work will be taken into account".	Not stated. Criteria exist but are privy only to examiners	"Taken into account when assessing marks".
? None	Via questions on the theory paper	Not stated	Small variable % via answers in theory papers.

TABLE 2 continued

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
Southern Univer- sities 1971	Not stated	a. The school district b. The study of simple geo- logical maps	a. Observation under natural conditions of agents of erosion and de- position, b. Practice in collection of specimens. c. Simple field- sketching. d. To cultivate scientific enquiry
WJEC 1974	Not stated	The general geology of an area. The study of geo- logical processes in the field including, a. Simple strati- graphical sequence. b. Major tectonic structures. c. Outcrop maps. d. Collection of specimens. e. Examination of contemporary geological processes. f. The relation- ship of geology to scenery.	a. The discipline of accurate observation. b. The discipline of accurate recording.
Northern Ireland Schools Exam. Council 1975	Not stated	School or any other area. Collection of rocks, minerals, fossils.	a. Sketching geo- logical phenomena b. Collection of rocks, minerals, fossils.

WJEC = Welsh Joint Education Committee

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
In answers in theory paper	Fieldwork question in theory paper compulsory	Unspecified mark schemes	Fieldwork question will carry equal marks
In answers in theory paper	Via questions in theory paper	Not stated	Small variable % via answers in theory papers
Field note-books are submitted for examination together with ancillary practical work	Not stated	Not stated	Not stated

TABLE 3 FIELDWORK REQUIREMENTS:

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
EMREB 1974 Mode I	3 minimum	a. Study of local area b. Landforms c. Building stones d. Mineral fossil rock collecting e. Geology of rock exposures	a. Accurate recording of data b. Interpreting evidence in rock exposures.
MXREB Draft Mode I dated 1972	3	Unstated but fieldwork said to be invaluable: a significant part of the work	None stated

EMREB = East Midlands Regional Examining Board

MXREB = Middlesex Regional Examining Board

CERTIFICATE OF SECONDARY EDUCATION			
Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
Personal observations in answers to written questions. Fully written up account of field visits (a main effort). Rough and final field notes	Inspection of fieldbooks. Internal assessment by teacher. External moderation (no interview)	Criteria stated for assessment of lab. but not field books. Evidence of collection by pupil other than on class visit	With practical up to 15%
Rough and final field notes	Inspection of fieldbooks. Internal assessment by teacher. External moderation	Not stated	With practical 30%

TABLE 3 continued

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
NWSSEB 1973 Mode I	$2\frac{1}{2}$ minimum	Field excursion recommended in first few weeks. Importance marked by provision of special pamphlet in which it is suggested that short studies are preferable to study of single area. Examples: a. Demonstration of geology of quarry section: rocks fossils sedimentation simple structures (e.g. bedding): economic uses. To be followed by pupils' own work on another but similar quarry. b. Transect: recording all information on six inch map. To be done in pairs. c. Local geology: to visit excavations: geology of school grounds: local building stones. d. Geomorphological exercise: river valley, coastal section, glacial valley. Extracurricular work welcomed. Collection of specimens can count but excessive collecting discouraged. Country code to be taught and strictly observed.	a. Learning from instructor. b. Practical investigation by self and in pairs. c. Disciplined observation. d. Interpretation and formation of reasoned conclusions. e. Sketching. f. Photography?

NWSSEB = North Western Regional Examining Board

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
a. Original notes prefaced by list of dated excursions. b. Written account of field studies not consisting largely of handout material or class notes. c. Extra-curricular work.	Internal assessment by teacher who provides: a. A brief confidential account of the work of each pupil. b. A mark out of 30. Extra curricular work to be marked. External moderation.	a. Presentation. b. Illustration. c. Personal observation. d. Personal collection. e. Completeness. f. Originality. g. Labelling, arrangement, usefullness of rock collection. The teacher is advised not to comment on pupils' rate of progress, perseverence, consistency of efforts, reliability in working unsupervised, or mark highly for number and rarity of specimens.	15%

TABLE 3 continued

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
SREB 1972 draft Mode I	Not stated	a. Collect specimens. b. Geological sections should be used to illustrate changing conditions of deposition.	Passive learning: pupils to be shown rocks in situ and relationships demonstrated.
YREB 1972 draft Mode I	Not stated	Not stated	(Not stated but basic objectives of whole assessment are to:- a. Recall basic facts. b. Observe and record basic information. c. Understand information. d. Apply geological knowledge in order to solve problems. e. Draw upon understanding to produce logical argument concerning the information.
WJEC 1973 Mode I	Not stated	Study the home area defined as the area accessible from school. Collection of rocks, minerals, fossils, photographs, maps.	a. Accurate observation. b. Labelling specimens? c. Photography?

SREB = Southern Regional Examining Board

YREB = Yorkshire Regional Examining Board

WJEC = Welsh Joint Education Committee

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
Evidence of fieldwork to be submitted via field note-books.	Not stated	Not stated	20% (but is an optional paper II of practical)
Field note-books.	Internal assessment by teacher. External moderation.	Not stated	5%
a. Loose leaf folder or field note-book. b. Personal collection of labelled rocks, minerals, fossils, photos, drawings, maps.	Oral class test. Internal assessment by teacher. External moderation of sample of pupils.	a. Variety of rocks b. Clear labelling. c. Neat notebook d. Presence of diagrams, sketches photographs.	With practical 30% (loose leaf folder or notebook 10%)

TABLE 3 continued

Board Syllabus Date	Number of days in field	Fieldwork content	Skills to be developed
WMREB 1972 Mode I	2½ minimum	Study an area. a. Origin and age of rocks and/ or minerals in relation to the strati- graphic column. b. The structure and texture of the rocks. c. The fossil content of rocks. d. The effect of geology on economic development.	None stated.
Perkins Mode III 1969	Not stated	The school area. Pupils need to be referred to actual example as often as possible. An individual project of greater depth than is possible in class. a. Thickness and dip of strata. b. Throw of faults. c. Attitude and type of fossils. d. Sketch plans of quarries and quarry faces. e. Sketch cross section of landscape or railway cuttings. f. Landscape sketches.	a. Seeing. b. Recording accurately. c. Field sketching.

WMREB = West Midlands Regional Examining Board

Presentation	Mode of assessment	Criteria of assessment	Percentage of total exam.
a. By answers to written paper. b. Original field note-book. c. Written up report. d. Drawings of specimens collected.	a. By written questions. b. Internal assessment by teacher. c. Work and marks must be available for external assessment.	Originality in writing up.	10%
a. Field note-books. b. Fieldwork report. c. Project report.	Internal assessment by teacher. External moderation.	Not stated	Notebook 6.7% Report 3.3% Project 6.7%

4. <u>Fieldwork arrangements in relation to the objectives of science teaching</u>

(i) Introduction. It is now worthwhile to examine:

a. the nature of the fieldwork encouraged by present syllabuses in relation to the experience of developing other science courses in the 1960's.

b. the modes of assessment of fieldwork in relation to modern techniques of assessment in science.

c. the criteria of assessment for fieldwork in relation to modern assessment in science.

The comments and analyses which follow must rest upon these assumptions:

a. that geology is a science

b. that the aim is to educate pupils <u>through</u> not <u>in</u> geological science

c. that the attempt is therefore to develop acceptable methods of teaching science through geology

d. that fieldwork, and methods of teaching fieldwork, as a form of practical work, can and should be compared with the best practical work and teaching of practical work offered in science in general.

e. that in any curriculum we should attempt to state what we mean as carefully as possible in order that as little confusion as possible should accrue from merely linguistic difficulties. All syllabuses are intended, within limits, to allow teachers freedom to teach as they wish, but it is sensible to state as clearly as possible what the examination will test, and hence allow judgement to be made about where it is possible to leave a prescribed route without harming the examination prospects of pupils.

f. that it is just simply inappropriate, even irrelevant, to examine practical work by a theory paper alone.

(ii) The development of new curricula, assessment procedures and attitudes in science education

A great deal has happened concerning the development of methods of teaching and assessing science since the

1960's. Scarcely any effect has been noticeable in geology teaching and examining so far, though a President of the Association of Teachers of Geology has pointed the way. Bassett (1971, p.72) wrote

> "It is not an exaggeration to claim that the teaching in science in general is at the threshold of a new and dramatic era. ... For the first time a massive effort is being made by scientists and educationalists to design entirely new curricula in almost every field of science."

Early in the decade, Kerr _et al_. (1963) and Eggleston (1966) questioned practising CSE and O level physics, chemistry, biology teachers as to the nature of both the practical work which they provided for their pupils and the work they would like to provide. These studies have been reviewed and added to (e.g. Eggleston and Kerr 1969; West 1972). At the same time work has proceeded on the way to go about stating and presenting any syllabus statements with respect to viable practical work. Basic rules for the identification of precise objectives of science teaching are now known. Tyler (1933) defined objectives as "changes in pupil behaviour which it is intended to bring about by learning." Adams and Torgerson (1964) stated that objectives should be defined in behavioural terms. They should be unambiguous precise statements allowing accurate communication, constitute non-overlapping categories, be discernible as the product of particular learning experiences, and each be assessable. Most agree that when syllabuses are constructed, strategic aims should be stated, and that definite objectives (i.e. attainable goals) should be set down in particular parts of a syllabus (see Table 6).

Objectives are often set down in terms of the classifications of Bloom _et al_. (1956), Bradfield and Moredock (1957), or Gronlund (1970). It is normal to concentrate on the measuring of both the hierarchically ranked intellectual (_cognitive_) skills (knowledge, comprehension, application, analysis, synthesis, evaluation)

TABLE 4 ABILITIES TO BE EXERCISED IN A GOOD PRACTICAL LESSON IN RANK ORDER ACCORDING TO PRACTISING TEACHERS AT C.S.E. AND O LEVEL

(Eggleston and Newbould, in Eggleston and Kerr 1969)

4.1. To think inductively and deductively: to draw conclusions
4.2. To observe and measure
4.3. To manipulate
4.4. To record accurately
4.5. To understand and follow instructions
(4.6. - 4.11. unranked)
4.6. To solve problems
4.7. To think out experiments
4.8. To be ingenious
4.9. To analyse data
4.10. To work methodically
4.11. To organise experiments

TABLE 5 THE PURPOSES OF PRACTICAL WORK IN YEARS 3 - 5 OF THE SECONDARY SCHOOL ACCORDING TO GRAMMAR, COMPREHENSIVE AND SECONDARY MODERN SCHOOL SCIENCE TEACHERS

(Data combined from surveys of Kerr and West: West 1972). Kerr's survey concerned 701 science teachers: West's 31 chemistry teachers.

5.1. To be an integral part of the process of finding facts by investigation and arriving at principles
5.2. To promote simple common sense scientific methods of thought
5.3. To make scientific phenomena more real through actual experience
5.4. To arouse and maintain interest in the subject
5.5. To encourage accurate observation and accurate recording
5.6. To elucidate theoretical work so as to aid comprehension
5.7. To give training in problem-solving
5.8. To develop manipulative skills
5.9. To fit the requirements of practical examination regulations
5.10. To verify facts and principles already taught

The rank order (most important first) of these purposes was as follows:

	1	2	3	4	5	6	7	8	9	10
West survey	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	5.10
Kerr survey	5.5	5.2	5.1	5.6	5.4	5.3	5.9	5.8	5.7	5.10

TABLE 6 STUDENT ATTRIBUTES SUGGESTED FOR ASSESSMENT IN NUFFIELD ADVANCED CHEMISTRY PRACTICAL WORK

6.1. Skill in observation
6.2. Ability to assess critically and evaluate the outcome of practical investigations
6.3. Ability to plan procedures and techniques for solving practical problems
6.4. Skills in manipulation
6.5. Attitudes towards practical work such as proper use of the laboratory and its facilities: persistence: originality, self-dependence.

TABLE 7 ANALYSIS OF PURPOSES, ABILITIES AND ATTRIBUTES OF TABLES 4, 5 and 6

Intellectual Skills (Cognitive Domain)					
	Level	Category	Abilities and purposes of Tables 4, 5 and 6		
lower	1	knowledge	4.10	5.9	
order	2	comprehension	4.1	5.1 5.6	
abilities	3	application			
	4	analysis	4.1 4.9 4.11		6.2
higher	5	synthesis	4.6 4.7 4.8	5.2? 5.7	6.3
order	6	evaluation	4.1		6.2
abilities					
Practical Skills (Psychomotor Domain)					
			4.2 4.3 4.4 4.10	5.3 5.5 5.8	6.1 6.4
Attitudes (Affective Domain)					
			4.8	5.2? 5.4	6.5

and the manipulative and practical (psychomotor) skills, and to question whether it is possible or desirable to measure personality changes (interests and attitudes - affective matters) with respect to science at all (see NWSSEB Table 3, column 7; but also Bollen 1972 and Duffey 1972). It is considered that any list of objectives for any part of any subject should be carefully specified in terms of the desired balance of low- and high-ranking cognitive objectives. Table 7 presents an analysis of the procedures set down in tables 4, 5 and 6 in terms of Bloom's classification.

Presumably, since there is so much here to choose from and reject, any material is put into a syllabus only because it is important. It is now axiomatic that if the material is important, like fieldwork, it should be assessed. To be assessed it needs to have objectives stated in both behavioural and operationally feasible terms. It is also axiomatic that assessment procedures should not distort acceptable and desired educational processes. The criteria of assessment which are to be used should always relate precisely to the aims and objectives.

In order for all these things to be accomplished, particularly with oral, aural and practical work, it has become accepted that a measure of internal assessment, either continuous (i.e. episodic) or terminal, is necessary. The Schools Council (1973, p.27-9) lists the strengths and weaknesses of internal assessment procedures succinctly and simply.

All these matters are easy to set down in theory but more difficult to put into practice. As West states (1972, p.148) ...

"learning experiences ... could be regarded as resulting from the interaction between a teacher, his resources and a number of external pressures ... a compromise between what the teacher wants to provide, and what he feels he can provide and what he should provide ... For the

science teacher the nature of the practical work his classes carry out results from his determined objectives as modified by resources of time, facilities, equipment, technicians, and external pressures usually in the form of exam requirements."

A more fundamental change has involved the educational system, which has long centred around knowledge and the teacher. Under the belated influence of Rousseau, Pestallozzi and Froebel the centre of gravity has shifted towards the individual learner and his behavioural characteristics. Harken to Rousseau:

"Teach your scholar to observe the phenomena of nature, you will soon arouse his curiosity, but if you will have it grow do not be in too great a hurry to satisfy his curiosity. Put the problems before him and let him solve them for himself, let him not be taught science, let him discover it. If ever you substitute authority for reason he will cease to reason and become a mere plaything of other people's thought."

Bassett (1971, p.73) has drawn the geologists' attention to this view:

"There seems little doubt that, as far as possible, a method of instruction should have the objective of leading the child to discover for itself. Telling children and then testing them on what they have been told inevitably has the effect of producing bench-bound learners whose motivation for learning is likely to be extrinsic to the task - pleasing the teacher, getting into university or college, or artificially maintaining self-esteem."

The implication is that real fieldwork should occupy an even higher position in geological education than it appears to do.

(iii) General comments on fieldwork arrangements in GCE and CSE syllabuses

It will be appreciated that the present arrangements for stating and assessing geological fieldwork as a practical activity of individual learners of science do not compare well with the developments outlined in the previous sub-section. Many statements do not concern behaviours. Objectives of doing fieldwork are not well stated. Statements are not clear and unambiguous, so that communication is difficult. The skills to be developed

are scarcely outlined, and what there are relate badly to the abilities which are exercised in good science lessons even when allowance is made for the different nature of geological science. Some cannot be assessed: many are not. Most published and unpublished criteria (e.g. p.9; 8-11) of assessment could relate to any subject, never mind science or geology. They relate either to the acquiring of knowledge or low-ranking skills. Criteria (1-7) as set out on p.9 relate to the professional competence and veracity of the teacher, who not only enters pupils for this examination but signifies that they have complied with the requirements of the syllabus. The examiners are measuring whether the teachers have complied with the syllabus. The criteria relate to competence in providing suitable learning experiences, and are only necessary because, (i) the syllabus does not state precisely the aims and objectives of the fieldwork, and (ii) some teachers, many presumably untrained in science teaching, are not aware enough to provide suitable experiences off their own bat. The aim, however, is not to assess the teacher's competence but the child's. The criteria and the assessment should relate to the degree of approved change in behaviour (i.e. learning) of the children over a range of practical skills which relate to real geology.

(iv) Detailed comments on fieldwork arrangements in GCE and CSE syllabuses

(A) Advanced and Ordinary Level of GCE

The number of days recommended for fieldwork is too often not stated. The ATG A level Survey showed that some schools interpret the regulations to mean that there is no need to do fieldwork at all. This proves to be true. From the statements in the syllabuses, schools could do as little at O level as they do at A level.

Objectives: (a) The content of fieldwork is imprecisely stated. There are too few words. These allow too little emphasis and make for poor communication of ideas. This

may be the cause of so little fieldwork being done by some schools; for it appears to be neglected by the syllabus. The statements compare badly with suggestions and specifications for practical work in most traditional science syllabuses, never mind modern syllabuses e.g. JMB Chemistry A level syllabus B, or the Nuffield schemes. Strangely, the content of O level geology schemes is slightly better specified than A level schemes.

(b) Skills. Imprecise terms; "experience", "keep a record", "adequate instruction", "experience in the field", "become familiar with", lead to poor communication. The learning experiences which are encouraged, if any, are again better stated for O level than A level, where the position is dire. If the only statement in a syllabus concerns passive instruction or demonstration by the teacher, then it appears that that is all that is needed. Who in physics, chemistry, biology would learn techniques and skills by watching? The range of abilities to be developed is too small; smaller for A than O level if words are taken at their face value. Inexperienced teachers receive no help.

Presentation: It is inappropriate to present evidence of practical work and fieldwork by answers to theory questions alone. This is unfortunately the case in many O level science subjects (e.g. physics and chemistry) where logistics are difficult because of numbers. It does not happen in A level sciences. It should not happen in geology if fieldwork is basic and numbers small. Often the field notebook is the only source of data for assessment. Anyone who has seen their variety would doubt their value as a potential measure of the work done. Some guidance could be given as to their arrangement and content. Displays of specimens do not always reflect the owner's diligence and skill: the rocks in the displays are sometimes not his property. It is best to restrict material for displays to specimens worked on and labelled at school.

Mode of assessment: It is inappropriate to examine practical work by theory questions alone. In that case the examination may be reliable overall but it will not be valid: it will be invalid with respect to statements about fieldwork, flimsily though the objectives are written. If the only way to assess fieldwork is by internal assessment then it should be done that way: there have been precedents within the GCE system (language dictées, domestic science, dissections in biology, etc.) The size of the administrative problem is often quoted as a reason for not having internal assessment. In geology where entries are less than 2% of the total both at A and O level, (D.E.S. statistics 1960-73), this cannot be the cause. Educationally it should not be according to modern principles. If fieldwork is important, it should be assessed: if not, it should be dropped.

Criteria of assessment: These are scarcely stated. Teachers and pupils deserve to know them. There is no case for secrecy if criteria are known: it is of course an embarrassment if they are said to exist and they do not. The author realises that it is very difficult if not impossible to mark fieldbooks as they are organised and presented at the moment, but this is not a good reason for devaluing the fieldwork which is alluded to in syllabuses.

Percentage of the examination total score: The marks given to fieldwork are derisory and emphasise yet again that the fundamentals are wrong. If something is educationally important, it should be scored highly. Time is spent by some teachers on fieldwork. Figures for A level (see p.7 above) refer to a mean of 11.3 days over two years: indeed the author now knows of a school where 30 days per year are spent in the field. If for argument's sake we take a mean of 10 days at A level per year, this (at 6 hours effective work per day) is equivalent to 160 lessons (plus follow-up work) over two years, and compares with 640 lessons in the whole course (assuming an eight

period week for 40 weeks per year). If some teachers feel that fieldwork deserves 25% of the time spent on the whole course, then it is a major activity. It should be scored at roughly the same proportion in assessment. At O level (four periods per week for 40 weeks for two years), a three day field course is equivalent to 24 lessons (plus follow up work) and is barely 10% of the time.

Backwash: The effect of GCE arrangements on a basic scientific activity like fieldwork is to allow it to diminish to nothing in some schools and to pervert its nature in nearly all. To examine practical work by theory questions, to allow any kind of book and notes to pass as a tolerable field notebook tends to encourage teachers to make fieldwork illustrate theory: fieldwork becomes less important, and is dealt with by the writing of notes about an outcrop, or worse, the dictating of notes; not by working on it. This relates to the curious phenomenon of the elevation of theory above practice (practical examinations always count less than theory exams). As Medawar (1967, p.121-2) puts it "the notion of purity has somehow been superimposed upon it, and now in a new usage that connotes a conscious and inexplicably self-righteous disengagement from the pressures of necessity and use." It relates also to Anglo-Saxon scientific tradition in schools and colleges which has been preoccupied with knowledge (and theoretical knowledge at that) until very recently.

It is to the credit of the few teachers who boost the mean values of days spent in the field that they refuse to be diverted. The GCE arrangements are seen to be professional only in the administrative sense. Boards are supposed to be the servants of the schools and have teacher-dominated committees. Is this working in practice?

(B) Certificate of Secondary Education

Number of days: The definition of requirements is a little better but still patchy. It is still possible to do no fieldwork and get away with it.

Objectives: (a) Content. This is very well stated in one case (NWSSEB), but absent or imprecise in others. Emphasis and communication in words are still poorly developed.

(b) Skills are reasonably varied and well stated in a few cases but not always very fully. There is a long way to go before a simple statement of the whole range of abilities to be developed is recognisable (see Schools Council 1969).

Presentation: Again there is some variety, but reliance on field notebooks, whose organisation is difficult to control, is weak.

Modes of assessment: are clearly stated. In the best case there is a considerable range of assessment procedures, which enable a wide range of abilities to be assessed quite effectively.

Criteria: are as badly stated as in GCE except in the case of one board (NWSSEB). The criteria, unfortunately, often have little or nothing to do with the scientific behaviours which are being learned and are criticised elsewhere in this article.

Percentage of the total score of the examination: The percentages are very varied. They are comparable to and justifiable in relation to the amount of time spent on the course (10%: calculated for a course of the same length as GCE O level). This means that the examination is valid in relation to the syllabus; the construction of the examination is technically sound. The author and many teachers believe that three days fieldwork per year is more realistic in relation to the development of adequate skills, and this would require an assessment nearer 20%.

Backwash: is generally good. Since they perform the internal assessment, teachers are forced to think hard of the learning experiences which they develop and the criteria of assessment. They can petition their

colleagues on preparatory committees much more easily. Internal assessment using sound criteria is the only way of assessing behaviours which have to be performed in the field, i.e. observing, recording, making hypotheses, predicting, testing hypotheses by going to another part of the outcrop. There is, however, a real difficulty of assessing large numbers. Some, cynics apart, will doubt the value of internal assessment and external moderation, and regard it as a glorious charade which leads to a certification of doubtful value. The author merely points out the complete absence of unarguable criteria for comparing grades in different subjects between different boards in external examinations despite the studies made by JMB (1966, 1970, 1971) NFER and Schools Council (1970). No system of moderation is easy to operate, and the author regards comparability over an area, region or country, as completely unproven as in GCE. The material, however, which has to be moderated *is* taught and the backwash is very healthy, for teachers are, for the first time really involved *en masse* in examining; they are asked to think about criteria for teaching and assessing; they go out of their classroom to see other schools' work. The inexperienced debate, discuss and probe as never before. This is not to say that difficulties do not arise with internal assessment: from changes of staff and students, the strain on relationships between them, and the extra workload placed on staff. Administrative matters apart, the examination is on its way to becoming professionally competent. It is much more so in some areas (NWSSEB) than others. There is still a long way to go.

5. Recommendations

(i) The aim of geological fieldwork is to have pupils geologise by themselves.

Science is a living activity. Primary knowledge is gained by individual learners doing science practically. This may require prior instruction and demonstration

(mostly in school), but pupils must do as much geology as possible by themselves. The former President of the Association of Teachers of Geology gives the lead, (Bassett, 1971, p.73):

"If, therefore, we accept the contention that intellectual activity is the same, whether we are considering the mental processes of a scientist at the frontiers of science or of a child in the lower levels of our secondary schools, then we should consider the child who is learning geology as a "geologist". ... it is much easier for a child to learn geology by behaving like a geologist than by doing something else. That "something else" usually involves what Jerome Bruner (1965) describes as a "middle language" - class room discussions and textbooks that talk about the conclusions in a field of inquiry rather than centering upon the inquiry itself."

Syllabuses should state clearly, preferably in the first paragraphs, that learning geology starts in the field, and that although time will restrict opportunities, pupils should each and individually have the opportunity to develop the skills cited below as soon as possible in their course, preferably in the first lession, and thereafter as frequently as possible.

(ii) Preferred organisation of fieldwork

At least two periods of personal investigation are suggested per field day at CSE and O level, but longer periods are obviously feasible at A level. The earliest excursions should use carefully structured exercises whose instructions are personalised via worksheets.

(iii) The objectives of fieldwork can be stated thus:

a. To understand and follow instructions.
b. To work methodically and individually except on rare occasions.
c. To observe as accurately as possible in a disciplined way.
d. To manipulate and use relevant simple tools (a list of appropriate tools could be stated: clinometer, orienteering compass, tape measure or rule, pencil, paper, on occasions a hammer, a weak acid bottle, a penknife).
e. To develop the habit of measuring quantitatively using SI units: to measure dips, azimuths, bed thicknesses, sizes of grains, number of fossils etc.

f. To record as accurately and methodically as possible at the outcrop. This can be done on loose paper (later to be put in a file) or in a field notebook (more long living but more likely to be lost) or by a camera. A list of suitable ways of recording data could be inserted, e.g. making a map of a small area, perhaps a quarry floor or an intertidal area, or making a scaled diagram (the author never used the word sketch).
g. To locate and reference any records; the test and the criterion for assessment being that an observer could go to and locate the exact spot many years later.
h. To locate, recognise and solve problems.
i. To think inductively and deductively: to draw conclusions and make hypotheses.
j. To think of ways of testing hypotheses. A list of suitable activities could be given, e.g. going to other parts of a quarry, stream or cliff and making new observations.
k. To follow up fieldwork and field identifications by making laboratory tests and identifications, and processing samples brought in from the field.
l. To analyse data and to write a report wherein the data are synthesised and evaluated.
m. To conserve geological data and countryside in general by reducing hammering and following country codes.

The variety of these objectives is such that some may be omitted for younger or less able pupils. Other objectives could be added, but they ought to be constructed according to Adam's guidelines (Adams and Torgerson 1964). These objectives all concern behaviours which are learning experiences.

(iv) Activities suitable for school fieldwork

Lists of activities which could be carried out by school-based parties are rarely published. Most activities need the careful preparation of individual worksheets before they are structured satisfactorily in relation to the objectives of the previous section. It is a great challenge to the teacher to produce two exercises per field day and it requires a great deal of preparation time. Once prepared and perfected, however, in terms of range of content and balance of skills, the exercises can be repeated from year to year, being only modified for the better. Exercises could be exchanged between schools. Some of the best

ought to be published. They need to be in much greater detail than those of Nuffield Secondary Science, Section 8.4: The Earth; (Leigh 1970).

(v) Objectives should be assessed both in the field and back at school

Each objective of section (iii) is operationally assessable or they would not be properly constructed objectives. Each agreed objective is a criterion for assessment whatever the content of the fieldwork exercise. Since each of the first ten objectives relate only to the field, assessment must therefore take place in the field. Failing the presence of an external examiner for each school, and the possibility of setting up a special test, such as developed at the University of Oxford, the only person able to do the assessing is the teacher: the CSE boards and teacher committees are quite right in having a component of internal assessment and requiring it to be externally moderated. Objectives k, l and m can be accomplished both in the field and in the study or classroom, and additional criteria will be needed to assess the quality of these behaviours. For the purposes of reporting internal assessment, it is necessary to reduce the number of categories of assessment to say, five. The following are suggested for CSE and O level, the last of which would be scored at twice the value of any other single category.

1. Ability to observe
2. Ability to record
3. Ability to manipulate
4. Ability to make hypotheses, predict, test hypotheses in the field
5. Ability to state a problem; analyse, synthesise and evaluate data relating to the problem and write a report explaining the solution of the problem in a simple way.

For A level the five categories might be different and include some of those of Nuffield 'A' level chemistry (Table 6).

We should not assess how pupils take instruction

or learn from demonstrations, or copy notes dictated at outcrop, or copy maps and diagrams from guides. Most of the criteria of assessment for A, O and CSE syllabuses at the present are inappropriate.

(vi) Feasibility and tactics in organising fieldwork

Some may say that headmasters and colleagues will not wear this "fieldwork lark". But at some time the headmaster allowed geology into the curriculum of the school and it was surely pointed out to him what was required to do the job properly. Once that decision was made then all efforts should be made to accomplish the task professionally. The author has yet to meet a headmaster who does not respond positively and sympathetically to a member of staff who goes to him with a well-prepared argument regarding what is desirable for the proper teaching of his subject. The argument should be backed by a pre-prepared series of worksheets which have been submitted to the headmaster beforehand. These will detail the fieldwork learning experience through which he intends his pupils to pass both on a coach and during two periods of personal investigation (each of two hours) during the course of a field day. With such approaches the teacher is likely to get his way before long. If when a subject has been accepted as part of the curriculum a headmaster stops a teacher doing what he considers essential for his teaching then he is close to obstructing the course of education. The same arguments go some way to mollifying obdurate colleagues. Regular afternoons set aside for geology or a double period at the end of the day which can stretch to teatime are not impossible to organise. Some teachers prefer these short opportunities to those presented by field days. The day before halfterm or full term are the most obvious times which are most readily agreeable for field trips, but it is essential to plan

some short fieldwork, if not a full-day excursion, in the first week. Lucky is the school with rocks in the grounds or the road outside, or with a stream in a local park, so that the afternoon or double period can be used.

At the university level, the Oxford University finals examination in geology compares very favourably in intent, organisation and assessment procedures, with the principles of teaching and assessing science which have been outlined in this article. The normal university practice of marking fieldwork by assessing the quality of a student's map (at a distance) and reading his thesis (often without specifying criteria of assessment) is less commendable, and has all the difficulties associated with the marking of a CSE project, or indeed a project at any level.

Addendum

Since this paper was written, copies of the AEB syllabuses for 1974 and 1975 have come to hand. In both reference is made to the new (1974) version of a pamphlet entitled "Suggestions on the organisation of fieldwork". This booklet is, in the author's opinion, quite excellent in the way it sets out the content and skills to be developed by O and A level pupils. The suggestions are detailed, practical and organisationally possible. They correspond closely with those advocated in this paper. Laboratory work directly relevant to field excursions is included in the assessment of O level. The method of assessment, by marking field notebooks by undisclosed criteria, remains the same, and is open to the same criticisms made in this paper of earlier and similar syllabuses. In the preface to the O level syllabus greater stress is laid upon fieldwork than hitherto.

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NOTES ON HUNSTANTON RED ROCK FOSSILS

H. Le Strange*

Marine Reptiles: a few odd bones of these are seen in The Sedgwick Museum of Geology in the University of Cambridge, and are in the special show case containing a fine collection of Red Chalk Fossils, all from Hunstanton. However it is very, very rare that any worthwhile reptile remains are to be seen, though indeterminate fragments are more common.

Fish (teeth and bones): are scarce compared to those in the White Chalk of Hunstanton cliffs.

Mollusca: I refer you to "The Geology of Norfolk" (1970), where on page 290 Dr. R. Casey has provided a revised list of fossil Mollusca from the Hunstanton Red Rock.

Lamellibranchia (= Bivalves). Splinters of *Inoceramus* occur by the million, and more or less perfect specimens are also quote common.

Gastropoda. I have seldom found these.

Belemnites. The Red Rock is absolutely riddled with specimens of small species of these, some over 5 cm long. There are no large species, as occur in some formations.

Ammonites. Well preserved specimens are on the rare side, though of course there are many poorer specimens.

This is also true of the Nautiloids, and it applies to *Cymatoceras hunstantonesis* (Foord and Crick).

Brachiopods. After belemnites the next commonest fossils are the brachiopods, known as *Terebratula dutempleana* (d'Orbigny). Specimens as large as the one shown in "British Mesozoic Fossils" are not too common. They vary greatly in size, and even shape, and may in due course get divided into several varieties.

Echinoderms. Do not forget to look out for the Crinoid

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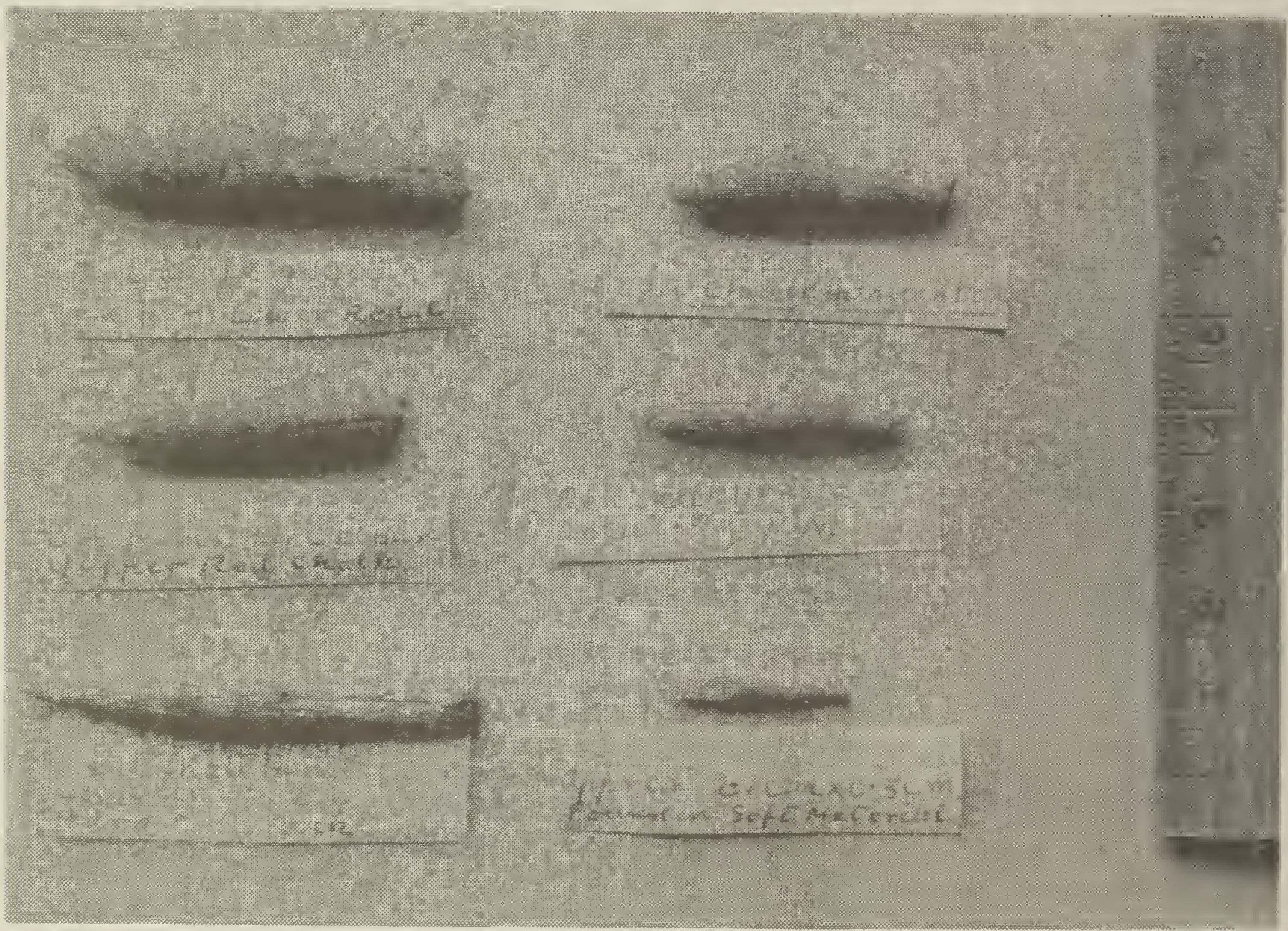
Torynocrinus with stem segments fused into a continuous circular column. This is fairly common, though a perfect specimen is not so often found. They are very fragile and difficult to extract. There is also the heart urchin Cardiaster. It is fairly common, and there are some of a "Cidaris" type.

Corals. The one and only species I so far know of in the Red Rock is of the solitary type, only $1\frac{1}{2}$ cm in diameter and known as "Podoseris mammiliformis" (Duncan). Only once have I found a specimen with two or more buds, though it is a common fossil at Hunstanton.



Neohibolites specimens from the H. Le Strange collection - Hunstanton Red Rock

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The Geological Society of Norfolk exists to promote the study and knowledge of geology, particularly in East Anglia, and holds monthly meetings throughout the year.

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Also available, at 75p (post free), is "The Geology of Norfolk", a 108 page book describing the geology of the county, reprinted by the Society in 1970; members of the Society may buy one copy only at 40p.